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A Framework to Evaluate the Financial Viability of Urban Public-Private Partnership Projects

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A Framework to Evaluate the Financial Viability of Urban Public-Private Partnership Projects

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Abstract

A Framework to Evaluate the Financial Viability of Urban Public-Private Partnership Projects

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As public governments around the world face limited funding capacity for capital-intensive projects, their attention is turned towards the private sector for financing. Public-private partnerships (PPPs) have emerged as an alternative project delivery method in which the public and private sectors work together for the provision of urban projects. In deciding whether to enter into a PPP agreement, both the public and private will have to conduct the financial viability of the partnership. This thesis aims to provide a framework for estimating a project's financial viability of large-scale urban projects, by addressing the crucial components associated with large-scale urban projects. These components include the type of PPP arrangement, contract length, financial structure, project cash flows, and capital budgeting. As part of the overall financial viability, the framework will also take into consideration the effects of uncertainties associated with a project or risks on the project's profitability; then, various risk management strategies that aim to provide better hedging of risks will be discussed.

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1. INTRODUCTION

With current economies experiencing difficulties in securing public funds for infrastructure, governments around the world are being faced with the challenge of being able to keep up with growing infrastructure needs. Failing to fund infrastructure projects could lead to detrimental effects on economic growth, which can in turn affect the local and regional job market, and the ability to attract new businesses and investments. Lack of economic development will also affect tax revenues, availability of government funding, and the ability to compete in an increasingly competitive state, regional national and global markets. The need for new funding sources has motivated the public sector to look towards private entities to provide funding for capital-intensive infrastructure projects, a trend that has been growing steadily in recent times (Savas E. , 2005; Savas E. , 2000; Yescombe, 2007; Li B. , Akintoye, Edwards, & Hardcastle, 2005). The private sector has also found that in many instances funding public infrastructure development is profitable and therefore of interest in a time when other investments have a lower yield, with a recent trend being that the private entity assumes responsibility of a facility for a set period of time (Savas E. , 2005) . The need for new public infrastructure funding sources and the desire for higher yield investments has encouraged public and private entities to partner together in what has become commonly known as a Public-Private Partnership (PPP). This joint partnership allows both parties, by combining their special skills, to achieve results that neither party could have achieved alone (Akintoye, Hardcastle, & Beck, 2003).

In addition to providing a monetary stimulus to undertake projects, the private sector's involvement has also included the actual construction, operation, and maintenance of certain infrastructure facilities. PPPs have taken many forms that range from performing maintenance works on an existing infrastructure to design, build, and finance, operate, and maintain new projects, as in the DBFOM contract type. Each PPP arrangement has its own characteristics and complexities, with each variation entailing a different type and amount of risk that each partner will have to handle. Therefore, despite PPPs providing a suitable alternative source of funding public infrastructure, developing such agreements is a complex and expensive process (Akintoye, Hardcastle, & Beck, 2003). Other PPP arrangements and contract types will be discussed in a later section of this thesis.

The urban environment has been one of the main adopters of PPPs in recent years, with several large-scale projects, both "greenfield" and "brownfield", being undertaken with the cooperation of both the public and private sectors. A "greenfield" project is one that is built on a new location where no facility existed before the PPP project, while a "brownfield" project is related to existing facilities that might be rehabilitated or reconstructed within the existing right of way. PPPs have become more common in a variety of fields such as transportation, social infrastructure (health facilities, schools etc.), public utilities, and government offices (Sagalyn, 2011). Private entities partner with the public sector to provide such urban development projects with the goal of achieving a certain return on an investment, and making profits. The public entity, on the other hand, has a duty to provide such services to the tax-paying public, and the addition of a profit-seeking private entity into the mix has caused some unrest among certain factions of the public (Yescombe, 2007).

In the transportation sector, toll roads are a common type of PPP project. The private entity can be involved in one of several ways, but with the ultimate goal of achieving profits. Therefore, questions have been raised whether turning to the private sector for the provision of services in the urban environment is the best route for the public sector, especially since the public sector could be able to procure a project at a lower cost.

However, this argument does not consider the fact that governments are often faced with limited funding alternatives and cannot undertake a project unless private funds are made available, taxes are raised or debt is incurred through government bonds. Therefore, in many instances, partnering with the private sector might be the most economically viable and publicly acceptable way to provide certain necessary capital and/or operational investments that are crucial to the construction, operation, and maintenance of facilities. Such investments have the potential to be recovered by the public sector in some cases through a boosted economy that provides a better standard of living to the taxpayers.

There has also been a growing need to spend more on existing infrastructure in order to maintain adequate performance standards for the public. The American Society of Civil Engineers (ASCE) Report Card of America's Infrastructure (ASCE, 2013)has estimated that approximately $3.6 trillion dollars will be needed to maintain the United States' current infrastructure at its current D+ score, a score that has been provided by the ASCE. This funding need does not consider additional, new transportation facilities that are needed to relieve congestion, improve freight operations and enhance economic competitiveness.

There exist a variety of considerations that should be studied to ensure the success of a PPP project. First, in order to be able to attract private investment, the project must be attractive to the investor. This can be achieved by decreasing the amount of risk that an investor might bear, and by offering the possibility of competitive and long-term revenue streams. In addition, governments may assist by offering special assistance, or certain financial guarantees, and by establishing a favorable legal and regulatory framework. The interests of the public sector; however, should not be compromised, and the expectations of both parties must be clearly stated at the onset of any partnership, with both parties ensuring that their joint fulfillment is a top priority. There are several methods that both the private and public entities utilize to assess the attractiveness of PPPs

Besides providing a source of funding governments, the private sector's involvement in the provision of infrastructure has other benefits. It is believed that the private entity can deliver a project faster, more efficiently, and with increased reliability (Kwak, Chih, & Ibbs, 2009). In addition, the quality of the infrastructure is also believed to be superior when a private partner is involved.

This thesis provides a framework for assessing the financial viability of urban PPP projects, with no specific focus on one industry or one geographical location, and by taking into consideration the interests of both the public and private partners. The objective of this thesis is to provide a framework that considers the following five elements in the analysis of financial viability: 1) the type of PPP arrangement, 2) the contract duration, 3) the financial structure 4) the revenues and costs, and the 5) various risks associated with the project. This framework provides a detailed consideration of all the input factors, and includes an extensive description of risk management, including tools and recommendations, which differ from existing efforts to describe PPP financial viability frameworks.

The thesis is organized as follows. Chapter 1 provides a review of the existing literature on project financial viability. Chapter 2 discusses the different project delivery methods that have been used. Chapter 3 provides the methodological framework for evaluating a project's financial viability. Chapter 4 will describe the inputs needed for the analysis, which include the type of PPP arrangement, the length of the contract, and the financial structure. Chapter 5 discusses the project's cash flow, in terms of revenues and costs. Chapter 6 provides an in depth discussion on the various risks that are associated with PPP projects and how they should be managed. Chapter 7 includes a summary of the financial metrics that can be used to assess the financial viability of PPPs. Finally, conclusions drawn from this study are provided in Chapter 8.

2. LITERATURE REVIEW

2.1 PPP vs. Public Procurement

Many studies have been aimed at comparing the features of a PPP and the public procurement of projects (Yescombe, 2007; Bult-Spiering & Dewulf, 2008; Burger & Hawkesworth, 2011; Grimsey & Lewis, 2007)... Contrary to the case of a standard design, bid, build (DBB) contract, which is a typical traditional delivery method of public infrastructure, PPPs offer another dimension to the financing, design, operations, and maintenance of public assets. In a DBB contract, the public authority designs and finances a project that will be constructed by a private contractor, using funding from tax revenues or public borrowing (Yescombe, 2007; Burger & Hawkesworth, 2011). The public entity assumes the full responsibility of funding the project, including cost overruns, and also operates and maintains the facility after completion of construction. As an alternative, PPPs provide the public entity with the option of financing projects using private funds, with the additional potential benefit of the private sector's expertise in providing large-scale infrastructure projects on time and with an expected quality level (World Bank, 2015; Sabol & Puentes, 2014; Grimsey & Lewis, 2007).

According to a study of 114 PPPs in 2009 by the UK's National Audit Office, around 70 percent of projects were delivered on time, with 65 percent being within the original budget. In addition, the University of Melbourne, in Australia, compared 42 projects procured under traditional delivery methods with 25 PPPs. They found that PPPs provide significantly greater cost certainty, with a cost escalation of 4 percent, compared to 18 percent with the traditional methods (PwC, 2010; Yescombe, 2007)

The nature of the relationship between the public and private sectors can take one of many forms. Different types of agreements between both entities exist, each with its own set of advantages, disadvantages, and complications. PPPs can be classified in a variety of ways, which include the structure of the agreement, the legal nature of involvement of the private sector, or according to the nature of the contracted service and the allocation of risk among the different parties (Yescombe, 2007) . The common forms of PPP arrangements that exist are: 1) services contracts, 2) operations and maintenance contracts, 3) design-build (DB), 3) build-operate-transfer (BOT), 4) build-own-operate-transfer, 5) design-build-operate-finance-maintain (DBOFM), and 6) concession agreements (GAO, 1999; FHWA, 2010; Asian Development Bank, 2008; Infrastructure Australia, 2008; Delmon, 2010).There are other forms of PPP arrangements that have been used, such as lease and affermage, and complete privatization, but they have not been included in this thesis for further discussion.

Another defining structure of a PPP agreement is related to how revenues are collected, and this could take one of two basic forms: user-based or government-based. In the former, revenues are collected directly from the users of the facility, such as tolls on toll roads, while the latter is based on the delivery of the facility, such as the delivery of a hospital according to specific quality standards (Yescombe, 2007; Farquharson, Mastle, Yescombe, & Encinas, 2011; World Bank; ADB; IDB, 2014). PPPs are also defined based on how they are procured. In that sense, a PPP could be funded using private finance, in which the private partner relies on the project's cash flows to obtain funding. This is also referred to as limited or non-recourse financing, or off-balance sheet financing. On the other hand, a PPP may be funded based on on-balance sheet financing. This means that the private partner will obtain funding based on its own balance sheet, without regard to the project itself and its own merits (FHWA, 2013; World Bank, 2015; Yescombe, 2007).

2.2 Financing of PPP Projects

PPPs have been viewed as a tool for off-balance sheet financing, but it also provides the public entity with the opportunity to invest in a project that would have otherwise not been procured at all. The funding of public-private partnership projects can be obtained in several ways. One such method is through government funding. As previously mentioned, the advantages of involving the private sector in the provision of public services are not limited to financial contributions. The private sector is also believed to bring expertise and efficiency into infrastructure provision, mainly through executing projects faster, providing better quality, and delivering with lower costs. That is why the government may choose to provide funding for some, or even all, of the project's costs. Examples of such a funding mechanism is in a Design-Build-Operate project, in which the government pays the private entity in lump-sums after completing certain stages of a project, and offering an operating fee to operate the facility (World Bank, 2014). In return, the public entity may receive revenue if excess revenues remain after paying the private entity.

Another funding mechanism is referred to as corporate finance, in which the private entity agrees to fund the project based on its own balance sheet, rather than on the project itself. This method might be riskier, since the private investor will have less borrowing capacity to fund other projects due to a rising debt to equity ratio. Therefore, this method is common for low-value projects that might not require off-balance sheet financing. This method, which is also referred to as on-balance sheet finance, has the benefit of a lower financing cost relative to funding the project on the basis of the project itself.

Project finance is one of the most common financing mechanisms of PPP projects. The project funding raised through loans or bond debt in this type of arrangement is secured based solely on the revenue streams of the project. A special purpose vehicle (SPV), with no existing business, is created to operate the project and provides for off-balance sheet financing, which is also referred to as limited or non-recourse financing (Fight, 2006; Finnerty, 2013; World Bank, 2014). One reason why a private entity might choose to finance a project based solely on the project's revenue streams is to share the risk in carrying out a project, due to the damage that the project may have on the company's own finances if the project fails to achieve expectations. (World Bank, 2015; Akintoye & Beck, 2009; Vinter, 2006).. Borrowing off a balance sheet means that the private entity would not have to show any borrowing for the project, and therefore would not risk its credit rating. This benefits the private entity since project debt would not hamper its attempts to raise money on the capital markets for other ventures (Finnerty, 2013; Fight, 2006; Vinter, 2006).

It must be noted that financing a project through private funds would be expected to cost more than using public funds, around 2-3 percent higher (Yescombe, 2007). This is due to the fact that the government is assumed to at low risk of default, which means it can generally borrow money at the lowest possible rate (Carmichael, 2015). However, the benefits of using private finance includes using less public money, the opportunity to procure projects that would have been otherwise unachievable, and allowing for faster investment in public infrastructure (Yescombe, 2007).

Moreover, there are several sources of financing for PPP projects, which include equity contributions, debt contributions, bank and performance guarantees, bond and capital market financing, and mezzanine financing (Finnerty, 2013; Fight, 2006; Akintoye & Beck, 2009; World Bank, 2014). The choice of which method to use will affect the risk that is borne by the private entity that is attempting to secure funds. These different financing sources will be discussed in a later section of this thesis.

2.3 PPP Risks

While there are many definitions of risk in the literature, the majority center on the main idea of potentially experiencing losses on a project due to the occurrence of a certain unfavorable event. One definition that will be used in this thesis is that of the Royal Society in Britain, which defines risk as 'the probability that a particular adverse event occurs during a stated period of time or results from a particular challenge' (Royal Society, 1983). Project risks can be classified in several ways, which help in understanding them, such as internal and external risks, project-specific and country-specific risks, based on the project phases that the risks belong to (Akintoye, Hardcastle, & Beck, 2003; Grimsey & Lewis, 2004; Pantelias & Zhang, 2010). Despite the varieties in classifying risks, the classification mainly serves as a way to understand the risks better, without major differences in the specific types of risks encompassed within each classification.

There has been research work focused on managing risks, and the related topics in risk management. The literature provides varying methods on how risk should be managed; however, the majority includes the same components: 1) risk identification, 2) risk analysis, and 3) risk mitigation. This method of risk management will be discussed further throughout this thesis. The first stage of the method involves identifying risks, and there has been ample literature that has attempted to provide a comprehensive view of risks in PPP projects. Several types of risks exist in the different stages of PPP projects, and they include: technical risk, construction risk, operating risk, revenue risk, financial risks, force majeure risk, regulatory/political risk, environmental risk, and project default, among others (Grimsey & Lewis, 2002; Akintoye, Hardcastle, & Beck, 2003; Asian Development Bank, 2008; Yescombe, 2007).

Within risk management, one area of study that has been growing is concerned with quantifying risks. There have been many studies that have been devoted specifically to using mathematical models and statistical tools to quantify risks including techniques such as Monte Carlo Simulation and the method of moments (Damnjanovic, 2006; Zhang & Damnjanovic, 2006; Zhao & Ono, 2001; Pantelias & Zhang, 2010).. There are methods that have been proliferating in fields of study other than infrastructure, particularly in finance, to quantitatively measure the effect of risks on PPP projects. Such methods include Bayesian analysis (Koller, 1999; Bedford & Cooke, 2001; Stone, 2013; Haimes, 1998), decision trees (Koller, 1999; Damodaran, 2008; Haimes, 1998), artificial neural networks (Chang M. , 2011; Jin & Zhang, 2011; Koller, 1999) , and value at risk (Jorion, 2000; Crouhy, Galai, & Mark, 2000; Best, 2000; Damodaran, Value at Risk, 2003).

2.4 Financial Viability

The assessment of the attractiveness, or measures of success, of PPP projects is accomplished through a financial viability analysis. The financial viability of a PPP project differs for the different stakeholders in the agreement. The public sector is believed to seek financial viability through obtaining the best value for money (VfM) (Yescombe, 2007). The value for money is not a measure of what is least expensive, but it accounts for the combination of risk transfer, whole-life project costs, and service provided by the facility. A popular method used to measure VfM is through the public sector comparator (PSC) (Quiggin, 2004; Cruz & Marquez, 2013; Grimsey & Lewis, 2002). Although there are several techniques for evaluating the VfM of a project, the PSC has been widely adopted and is one of the most commonly used methods. The PSC essentially evaluates the difference in cost between undertaking the project without a private partner or through a

PPP. In some cases, when attempting to compare to the case of the government performing the project without a private partner, an alternative cannot be estimated, which means that if the project is not undertaken as a PPP, it will not be procured at all.

For the private partner, the main objective of entering into a PPP agreement is profitability and return on investment. The private partner will conduct a financial viability assessment by looking, mainly, at the project's cash flows. Also, the private partner will make a decision on how to finance the project, by assessing the options of project finance or on-balance sheet financing. This will affect the lender's decision in participating in the PPP. As a result, and from the lender's perspective, achieving financial viability is done through the repayment of debt, which involves the analysis of the project's costs and revenues. Essentially, for a commercial lender, if the project's revenue streams are not attractive it will not participate in the project. For the analysis of the attractiveness of the revenue streams of the project, and comparing with the project's costs to estimate profits, several financial metrics are used. In order to assess the profitability and the attractiveness of a project, the cash flows and the amount invested must be analyzed. Two of the most common methods to analyze the profitability and attractiveness of long-term investments in projects, for both the private partners and their lenders, include the Net Present Value (NPV) analysis and the Internal Rate of Return (IRR) (Yescombe, 2007; Zhang X. , 2005).

One of the main sources of funds for a project is through commercial debt, and the ability of the private partner to repay its debt is crucial to the success of any PPP. Therefore, specific cover ratios (CRs) such as the Annual Debt Service Cover Ratio (ADSCR) and the Loan Life Cover Ratio (LLCR) are used by lenders to evaluate the borrower's ability to repay its debt, and thus the attractiveness of a PPP endeavor. Commercial banks, under common PPP arrangements, are not entitled to a share of the project's profits, and combined with the attitude of the world's banking regulations, which have become stricter after the recent financial crisis in 2007, make commercial lenders risk averse. Therefore, banks will conduct an in depth, due diligence financial analysis before agreeing to participate in a PPP project. Other non-commercial lenders might have other metrics for the evaluation of project attractiveness, such as promoting a country's industry in the case of an export credit agency (Vinter, 2006). PPPs are also funded partly by equity. It is common for equity to make up a smaller share than debt of the total funds that are required for a project. The main equity contributors to a project are the private partners themselves, but governments and lenders have also provided equity funding to PPPs in the past (Finnerty, 2013; World Bank, 2014; Fight, 2006).

This chapter provides a literature review on the main components that make up the framework presented in this thesis. A brief overview on the distinction between PPPs and public procurement is given, and it was found that PPPs have emerged as a viable alternative to traditional public procurement in some cases. In addition, a review of the financing alternatives of PPPs was presented. It was found that there are several options available to the project partners who wish to undertake a PPP project, and they will be discussed in greater detail in a later chapter of this thesis. Moreover, a review of risk management in PPP projects was conducted and it was found that most procedures focus on three main stages: risk identification, assessment, and mitigation. Finally, a review of the financial viability analysis metrics was presented, and several metrics were found to be commonly used, such as the NPV, IRR, and the VfM analysis for PPP projects. The following chapter will detail the methodological framework that is proposed by this thesis on assessing the financial viability of PPP projects, followed by subsequent chapters that will discuss in greater detail the elements of the framework.

3. METHODOLOGICAL FRAMEWORK

3.1 Description

Figure 3.1 illustrates a framework showing the overall interaction of all the factors in a PPP, which are crucial to the determination of the financial viability of a project. As shown in the figure, the main elements of a PPP interact with each other and affect the financial outcome of a project. The PPP agreement between the public owner of the project and the private investors involves a complex network of relationships among financing, risks, revenues and costs that need to be analyzed to determine whether an investment would be profitable or not. The process involved in determining a project's financial viability starts with analyzing the PPP agreement, the contract duration, and the financial structure. With this information, the revenues and costs of the project can be identified, and a cash flow constructed. However, it is important to note the effect of risks on a project's cash flow, and an adjusted cash flow should be constructed after the risk management stage. Afterwards, financial metrics are used to determine a project's financial viability.

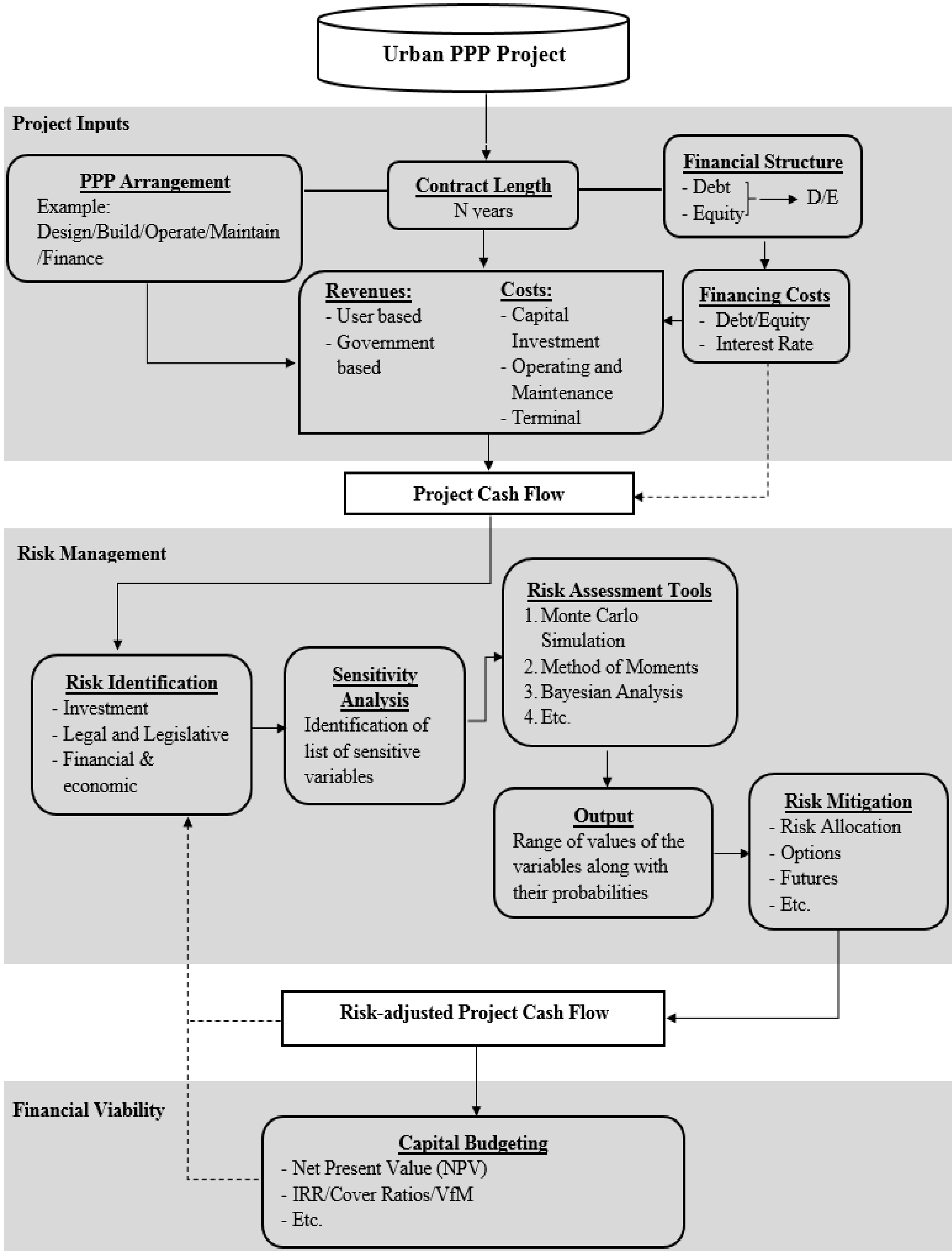

Figure 3.1 PPP Methodological Framework

3.1.1 Project Inputs

The owner of the facility, i.e. the public sector, is the main decision maker on whether to procure the project through a PPP or another delivery method. Once the decision on selecting a PPP as the delivery method is made, and a specific PPP arrangement is decided upon, a contract is drafted between the owner and the private sector defining the details of the project, following a request for proposals and the identification of the preferred private company bidder. The contract would include the scope of the project, the level of involvement of each partner, the length of the agreement, the financial structure, the revenue source scheme of the private entity, and the allocation of risks.

The PPP arrangement and the financial structure will determine the costs and estimate the revenues of the project, and in combination with the length of the contract the project's cash flows can be constructed. The costs and revenues will serve as inputs to the risk management stage, in which they will be adjusted for risk.

3.1.2 Risk Management

PPPs provide the public entity with a method of transferring more risk-s to the private partner. A risk management strategy is described in this thesis that involves three successive stages: risk identification, risk assessment, and risk mitigation. The three processes combine to give project managers a better understanding of the risks that might occur, the potential impacts of the risks, and how the risk impacts can be reduced. The thesis provides a discussion on risk management, and describes several methods to quantify the impact of risk on projects. After considering options for risk management, a more accurate cash flow can be constructed and analyzed for assessing financial viability.

In the risk identification stage, all the project risks will be identified , and will serve as inputs to the sensitivity analysis After conducting the sensitivity analysis, a list of the most sensitive variables is identified, $X = \{x_1, x_2, \dots, x_n\}$, where x_i refers to a sensitive risk variable. These sensitive variables are then assessed using the risk assessment methods proposed in this thesis, such as Monte Carlo Simulation and the Method of Moments. The output of the risk assessment method will be the distributions of revenues and costs, along with their expected values and standard deviations. That is, probability distributions for each sensitive variable are generated. As an example, consider user-based revenues, described here as a function of the values of the sensitive variables $U(X)$. The variation in user-based revenues, with changes in the sensitive variables, will be studied, and a probability distribution of the user-based revenues will be produced; $(u_1, p_1), (u_2, p_2), \dots, (u_n, p_n)$. This is done concurrently for all revenue and cost components, other than user-based revenues, in order to obtain expected values of revenues and costs. Finally, after identifying the risk-adjusted revenue and cost components, risk mitigation practices and tools are implemented.

The output from the risk management stage will be revenue and cost variables that will be used to construct the risk-adjusted cash flow. This framework focuses on a risk management strategy that provides additional detail to what is already present in the literature. It combines tools and concepts from various literature sources and from various fields of study, as will be discussed later in the thesis, to provide one comprehensive framework that includes a detailed methodology for risk management. The risk management process is at the core of this framework, which aims at providing a more accurate financial viability procedure.

3.1.3 FINANCIAL VIABILITY

The final decision of a project's financial viability is determined t after considering several financial metrics and ratios using the risk adjusted values expressed in the modified cash flow. This thesis describes these metrics and discusses how they can be used to assess a project's profitability. For example, the Net Present Value (NPV) of the investment, a metric which is described in Chapter 8, is calculated using Equation 3.1 below.

$$NPV = \sum_{t=1}^{N} \frac{(R - C)_n}{(1 + i)^n} - CI \tag{3.1}$$

Where:

$(R - C)_n$: The difference in risk adjusted revenues and costs for each year of the analysis

CI: Capital Investment, referring to the initial investment in the project

i: Project's discount rate

N: Project's contract duration

The public sector, in its process of analyzing a project's financial viability, compares the potential gains and/or losses due to selecting a PPP instead of other more traditional procurement methods. After using the financial metrics and conducting the necessary analysis, a decision is arrived on whether to proceed with the PPP venture or not.

A project's procurement method is one of the most important considerations stakeholders must account for before undertaking an investment. Project delivery methods have evolved over the years, from the most traditional method, the Design Bid Build

(DBB), to having a construction manager at risk (CMAR), and a Design Build (DB) strategy, all of which will be discussed in Chapter 4. Considering that each delivery method has an effect on the budget, schedule, and risk of the project, the choice of project delivery method should take into consideration these effects, as well as the stakeholders' expertise, at the earliest stages of project procurement. The following chapter aims to provide a discussion on the most common project delivery methods, and presenting their advantages and disadvantages.

The chapters that follow will discuss the elements that make up the three main components of the methodological framework presented in this chapter. Chapter 4 will start with an overview of different project delivery methods to justify the use of a PPP on projects.

4. PROJECT DELIVERY METHODS: COMPARISON AND EMERGENCE OF PPPs

A project delivery method is a process that dictates the overall scope of a project in terms of design, construction, maintenance, including the interaction among the project stakeholders. It encompasses a wide array of project variables, from the overall project delivery structure to the final closeout deliverables, including the financing details, risk allocation, scheduling of design and construction operations,, and maintenance responsibilities (TCRP, 2009). The project delivery method involves setting the contractual nature among the project stakeholders necessary to undertake a project. Inefficiencies in the performance of projects particularly due to cost, quality, and time to completion of projects led to the evolution of project delivery methods from DBB to current hybrid systems such as DB, for example (TCRP, 2009; CMAA, 2012).

The traditional design-bid-build (DBB) method involves three sequential and separate phases: design, bid, and build. The design phase often involves contracting with a designer or architect to fully complete a design for the project. The bidding phase is when a contractor is chosen to build the project, using the design documents completed by the designer in the design phase, and based on fixed-price, total cost considerations. Finally, based on the decision of the bidding phase, a contractor is chosen and the project is built during the build phase. This linear method has been popular throughout the 20th century, especially in the U.S., and it involves three main participants: the owner, the designer, and the contractor, and two main contracts: owner-designer and owner-contractor. The owner-designer contract, however, might not exist if the owner is the designer. The contractual nature and the interaction between the project stakeholders are relatively simple to understand and are clearly defined, which is one advantage of this method.

Several drawbacks exist, however, mainly due to the contract structure of the DBB method. After the design phase, the owner receives the project's design, and the relationship with the designer ends. This means that, during the construction phase, the owner is held liable for any faulty design, which means the cost is borne by the owner during the remainder of the project. Moreover, DBB contracts are commonly awarded to the lowest bidder, and in such cases this means that contractors, who generally submit a low bid on a project, would resort to increasing the costs of items that might be subject to change orders that are initiated by the owner or the contractors themselves, in order to generate profit from the project. This approach allocates the design risk to the owner of the project and, in fact, most of the project risks are borne by the project's owner, since it is the main participant of the contracts.

In an attempt to resolve the deficiencies of a DBB contract, a construction manager (CM) may be added to the agreement that primarily assumes the performance risk of a project. This method is referred to as Construction Manager at Risk (CMAR), whereby the CM guarantees the delivery of a project according to a fixed schedule and/or budget. One common element of the CMAR contract is that the CM generally offers a guaranteed maximum price (GMP), which sets the maximum possible cost that the owner will pay, thereby transferring the risks of paying over that price to the CM. Another common element of the CMAR contract is the involvement of the CM during the design phase of the project, and thus communicating with the designer. This also reduces a portion of the design risk that the owner must bear, who might not have the necessary resources or expertise to manage the project design or evaluate constructability issues that can be addressed by the CM construction expert team. This could also mean that there may be an overlap between the design and construction phases – an option that is used to expedite project delivery and reduce the project delivery schedule

In this delivery method, there are three main participants: the owner, the designer, and the CM, and two separate contracts are agreed: owner-designer and owner-CM. The selection of the winning bid is made based on its best value being offered based on 1) lowest and best bid, 2) bid price + project time to completion (A + B) or other options.

A third project delivery method that has gained popularity in recent years is the design build (DB) method. In a DB structure, the owner contracts out both the design and the construction to one entity, reducing the complexity of multiple participants. The DB entity is required to guarantee a fixed price to the contractor for both design and construction, meaning that performance-related risks are transferred away from the owner, as long as the contract and performance period covers the entire design life of the infrastructure. The selection of the winning entity is made based on technical merit and price, rather than lowest cost alone.

Due to the nature of the DB contract, the designer receives input from the constructor during the design phase, which allows for an overlap of the design and construction phases. This often leads to projects completed under a DB contract to be faster than those under a CMAR or DBB contract. The overlapping of phases also leads to some construction related decisions taking place after the design phase, which contributes to both the faster deliver time and the lower overall design risk. However, there is a risk that a design change is proposed after construction has commenced. In such cases, the entity that initiates the change will bear its risk. For example, if a change in design is required because of faulty designs by the DB entity, then it will have to bear this risk. This chapter provides a summary of the different traditional project delivery methods that are commonly used, which are DBB, CMAR and DBB. They are compared with each other, by detailing the advantages and disadvantages of each for the purpose of ultimately comparing with a PPP, in order to justify the use of a PPP as a project delivery method. It was found, from both the literature review as well as the discussion in this chapter, that a PPP can offer significant benefits, particularly when the public entity does not have the necessary funds to procure the project. Moreover, PPPs offer the advantage of transferring project risks to the entity that is best able to handle them. Finally, PPPs can also offer the advantage of efficiency and expertise in undertaking a project.

After establishing the need for a PPP, its financial viability must be studied. The following chapter will provide the first step in the financial viability framework proposed by this Thesis, and will discuss the main inputs to the framework proposed in this Thesis.

5. INPUTS TO THE FRAMEWORK: PROJECT INFORMATION

Assessing the financial viability of a PPP project is very much dependent on the specifics of each project. PPPs mainly differ in duration, scope, contract type, financial structure, and risk sharing. This chapter will discuss the differences related to concession length, project scope, PPP arrangements, and financial structure, as well as their impact on the outcome of a project's financial viability.

5.1 Concession Term

When the PPP contract is being agreed between the SPV and the public entity, the interests of both parties need to be addressed. One contractual feature that plays a significant role in the interests of the partners, and ultimately in the financial viability of the project as a whole, is the length of the concession, or the concession term. The concession term is usually determined after analyzing the project's cash flow, in order to provide ample time for the private sector to generate revenues for the repayment of debt, and make a profitable return on its investment. In addition, the public will want to define the length of PPP projects so as to incentivize good asset management (FHWA, 2010). The public sector will aim to select a duration that allows for a balance between its objectives and those of the private sector. While governments should provide the private sector with the ability to regain all of what it has invested in the asset, while also generating profits, it should also not forgo potential revenues for more than the necessary duration to provide users with the required service (FHWA, 2010).

5.1.1 Concession Term Options

The FHWA has identified three main concession term options that public sectors consider when deciding on the duration of a PPP project: fixed, dynamic, and extendable. A fixed project duration is one in which a specified term is set by legislation or in negotiations with the concessionaire. In Texas, for example, the maximum allowable duration for a concession project is 52 years (TxDOT, 2015). The fixed term is usually set to be greater than the asset life of the project, which would allow the private entity to accrue depreciation and tax benefits. A dynamic concession term does not end at a pre-specified date, but rather when a pre-specified target is met. For example, a concessionaire might agree to end a concession when it has entirely repaid its debt for the project. The dynamic term usually ends when an agreed rate of return is achieved, when debt is repaid, or when other pre-determined milestones occur. Extendable terms are usually offered as a possible compensation option when the fixed concession term expires, but the concessionaire requires some sort of compensation from the public sector. For example, the California Department of Transportation offered an extension to the concession in order to compensate the Presidio Parkway concessionaire for delayed costs or extra work costs (FHWA, 2010).

5.1.2 Determining the Concession Term

As previously stated, one common method used to determine the length of the contract in a PPP agreement is based on the project's cash flows. The concession term is usually selected to ensure that the private partner is able to generate the necessary revenues, while also maintaining adequate service to the taxpayers. In addition, there are two other methods found in literature that have also been used to determine the length of the concession. The first is the use of game theory whereby the concession term is negotiated in a dynamic process. The process continues, as each party will attempt to maximize its benefits, before settling on a length that satisfies both parties' basic requirements. The second strategy is the use of simulation, such as Monte Carlo Simulation. The different variables that affect the choice of concession length, including the NPV, capital investment, revenue streams, discount rate, risks, and construction period, are simulated to determine the optimal concession length that will provide a 'win-win' situation for both parties (Carbonara, Costantino, & Pellegrino, 2014; Peng, Cui, & Chen, 2014). Furthermore, simulation models attempting to find a concession period that is of lower risk to the private partner were also developed using the minimum, expected, and maximum internal rate of return (IRR) (Ng, Xie, Cheung, & Jefferies, 2007).

The concession term is one of the main inputs in the financial viability analysis of any project. It is also one of the most important elements of a PPP agreement, since its value is a main determinant of the gains or losses of both partners in the agreement.

5.2 PPP Arrangements

PPP contracts can be structured in many ways, with differing levels of authority given to each party, and different risk levels attributed in each agreement. The contract types also determine the revenue sources of the private party, and how payments are made. To illustrate these points, the following common contract types will be discussed along with their main differences:

- Services Contract
- Operations and Maintenance Contract
- Design Build (DB)
- Build Operate Transfer (BOT)
- Design Build Finance Operate Maintain (DBFOM)
- Concession

Figure 5.1 below, based on Delmon (2010), shows the different degrees of control between the private and public sector, as well as the different management responsibilities, of each PPP arrangement.

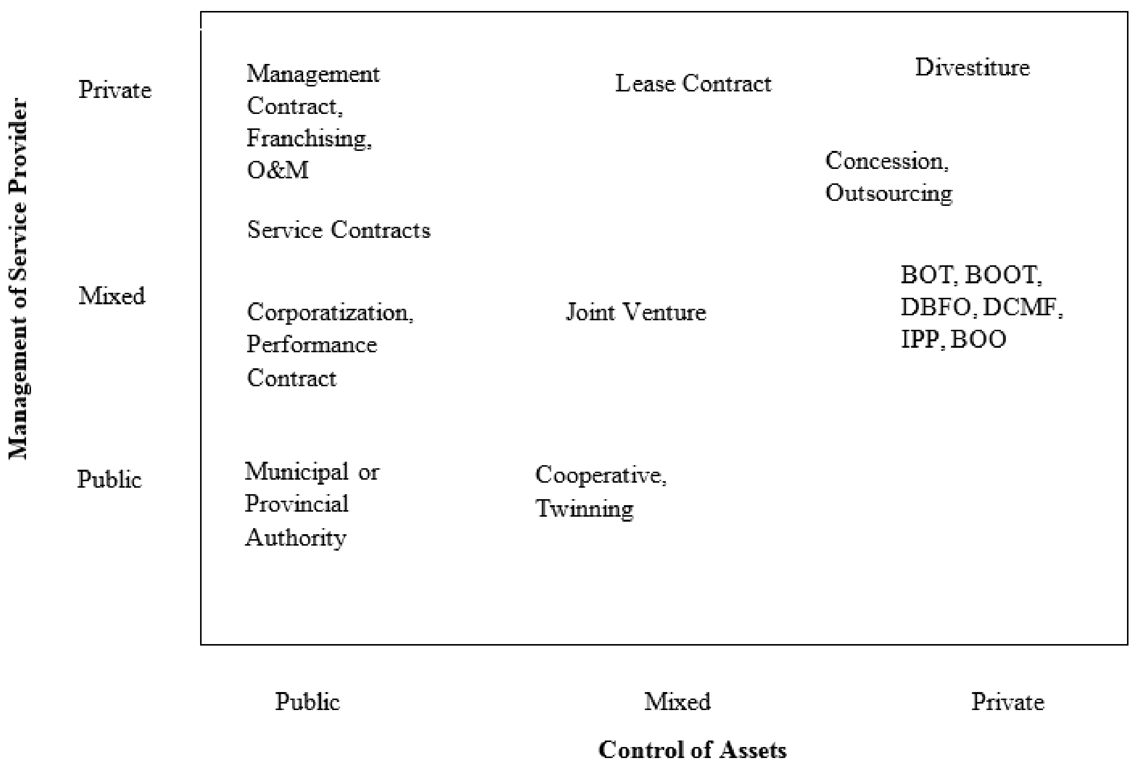

Figure 5.1 Comparison of Public and Private Sector Involvement in PPP Arrangements (Delmon, 2010)

5.2.1 Services Contract

A service contract is a common type of PPP arrangement, and in fact, it is the most used PPP arrangement in Asia (Asian Development Bank, 2008). With a service contract, the public authority hires a private entity to complete contracted tasks at a fixed budget, and typically according to performance standards. Such contracts are typically short term, whereby the public authority retains ownership of the asset, while paying the private partner a pre-determined fee. This type of contract is typically used when support services are required, such as customer services and billing on toll roads, for example. Service contracts are also used in the utilities sector, in which laying pipes or purchasing spare parts are necessary. Most importantly, this type of contract is selected when it is believed that the private entity would improve the efficiency of the work. It is also the case that several service contracts are signed by a public entity, either for the same project or for multiple projects, and therefore a strong enforcement of the contract laws is required, in addition to the ability to manage several contracts.

5.2.2 Operations and Maintenance Contract

An operations and maintenance (O&M) arrangement involves a public partner contracting the operations and maintenance of a facility to a private entity. Under this type of agreement, the public partner would retain ownership and management of the facility. One variation to the O&M arrangement includes contracting out management of the facility to a private partner. The public entity would also retain ownership of the facility in this case, but it opens the door for the private partner to invest its own money in the project

(PPP Council, 2015; World Bank, 2014; GAO, 1999). This type of agreement is common in wastewater treatment services.

5.2.3 Design Build

A design build (DB) contract is one in which the public sector agrees with a private partner to design and construct an infrastructure asset. The private partner does not own the asset at any point, and immediately after the facility is built, it is handed over to the public partner. Therefore, a DB contract is usually agreed when a new facility is to be built (World Bank, 2014; NCPP, 2015; GAO, 1999) .

5.2.4 Build Operate Transfer

In a build-operate-transfer contract (BOT), the private partner builds a facility, and operates it for a brief period of time before transferring it to the public entity. The private partner is usually paid for its services by the public entity, rather than receiving revenues from the users directly, which means that the revenue risks of the facility lie with the public partner. At the end of the contract period, the facility is transferred to the public sector, which in turn assumes the revenue-related risks of the project. BOT projects are most common when developing new infrastructure assets such as a dam or power plant, rather than an existing asset, and are one of the most common PPP contract types in Europe and Asia (World Bank, 2014).

One variant of the BOT approach is the build-own-operate-transfer (BOOT) contract. In a BOOT agreement, the ownership of the facility is temporarily shifted to the private partner for the length of the concession during which the project's revenue risks are transferred to the private entity. Another variation is the build-own-operate (BOO) approach, in which the private partner owns the facility until it decides to sell it off after a certain period of time. With a BOO, the revenue risks lie with the private partner, similar to BOOT (Menheere & Pollalis, 1996).

5.2.5 DESIGN BUILD FINANCE OPERATE MAINTAIN

A design build finance operate maintain (DBFOM) contract is usually agreed when the private partner is expected to handle the responsibilities of designing, building, financing, operating, and maintaining the infrastructure. Even though the specifics of DBFOM contracts can vary, most of the private partner's revenue streams are from direct user fees, such as tolls, while availability payments have also been used. In order to finance the project, the private entity leverages future revenues to raise debt in order to finance the project (FHWA, 2010; PPP Council, 2015; Infrastructure Australia, 2008; World Bank, 2014).

Two other forms of the DBFOM contract exist; whereby one or more of the services offered by the private partner differ. Examples of such forms are DBFO and DBFOMT. In a DBFO contract, the private partner does not assume the responsibility for maintaining the facility, and thus is relieved of the maintenance risk associated with the project. Another form of the DBFOM exists, in which the private partner owns the facility during the length of the contract and transfers it back to the public sector afterwards. This arrangement, referred to as a DBFOMT, is common abroad; however, it has rarely been used in the United States (GAO, 1999).

5.2.6 CONCESSION

A concession involves leasing a facility to a private partner who operates and maintains the facility for a certain time period, during which they have the right to collect tolls. One of the most important criteria for awarding a bid to a private partner is the concession fee that is paid to the government. In addition, other important criteria include the length of the concession and the credit worthiness and expertise of the private partner (FHWA, 2014; PPP Council, 2015; NCPP, 2015; GAO, 1999; Asian Development Bank, 2008; World Bank, 2014).

The arrangements discussed above do not exhaust the full spectrum of possible PPP agreements that can be structured. The study of the different forms that a PPP can take is essential in determining the risk that each party will bear in the agreement (World Bank, 2014). As such, careful consideration needs to be used in determining the ideal structure for each project. As projects vary, so do their needs, requirements, and complexities; therefore, each project will need a careful analysis on what PPP arrangement to choose. This means that there is not one PPP contract that suits all projects, and the work involved in structuring a PPP agreement should be handled with the utmost care.

The definitions of the different PPP arrangements are not always clearly defined in the literature, and participants must be aware of any laws that the host country might have that clearly define these arrangements. Therefore, in constructing the optimal PPP agreement for each project, legal advice must be consulted to understand the full implications of all decisions made.

The ultimate goal of a PPP arrangement is to allow a certain project to flourish in ways that each partner would not have been able to achieve alone. Therefore, in structuring the PPP arrangement, success is based on the appropriate distribution of risks that forms proper co-dependency between the partners, allowing each to achieve their goals (European Commission, 2003). For this reason, the PPP structure is a crucial first step in embarking on a successful partnership between the public and private sectors.

5.3 PPP Financing

Prior to bidding on any project, the private partner must have a secured funding source that will enable them to procure the project. There are several sources of funding for PPP private partners, which are subdivided into two main categories: public funds and private funds. The public sector offers funding options that could be used in PPP projects, which are mainly in the form of grants. The private sector also offers several funding alternatives, and it is the main financier of PPP projects. In addition to obtaining funds from lenders, the private partner can also rely on the project's revenue streams for funding, and this is referred to as project finance. The funding sources will be discussed further in this section, in addition to the concept of project finance (Finnerty, 2013).

5.3.1 PROJECT FINANCING

The term "project finance" refers to raising the funds for a project solely based on its cash flow, and on a limited or nonrecourse basis. The project stakeholders create a special purpose vehicle (SPV), which is a separate entity created for a particular project and to secure funds for that project, in order to isolate themselves from the financial risks that the project may bring (Reuters, 2015). That is, the SPV secures debt based on the project's cash flows, without relation to the parent companies' activities. By doing that, the parent companies are shielded from the potential financial risks that may occur as part of the project. For example, if a project's cash flows fail to secure the necessary funds to repay its debt obligations, and the SPV declares bankruptcy, the parent companies' balance sheets will not be affected. Moreover, by borrowing off the parent companies' balance sheets, the parent company's borrowing capacity is not affected, allowing it to undertake more projects at the same time.

Project financing is used when a project is able to function independently and based on its own cash flows, and this is a requirement that lenders will seek before agreeing to invest in the project. Some examples of project assets that have been financed on a project basis, as part of a project financing scheme, electric generating facilities, hydroelectric projects, wastewater treatment plants, and toll roads.

Project finance has been a common feature of PPP projects and a preferred method for raising long-term debt financing. In addition, the high costs associated with project financing make it unsuitable for short-term, smaller scale projects (FHWA, 2013). Several benefits exist that encourage the private partner to use project finance as a method to raise funds, and they include higher leverage, risk limitation, and non-recourse financing.

Leverage is referred to as the amount of debt used to finance the project (Ehrhardt & Irwin, 2004). Allowing a higher level of debt, as opposed to requiring a higher amount of equity, makes it easier for the private company to achieve return on equity and the required equity internal rate of return.. In addition, raising equity is more troublesome than raising debt given that more investors might need to be included in the project, making this an additional advantage to high leverage.

Risks of a PPP project can also be limited when using project finance. The inclusion of a number of investors creates a risk sharing mechanism in which the consequences of risks are shared among the investors. However, increasing the number of partners also means that profits have to be shared among them, which ultimately leaves less profit for each of the partners. Therefore, despite the fact that risk is hedged when the number of partners is increased, less profit will remain for the stakeholders.

Lending at the project level without regard to the balance sheets of its parent companies, as previously mentioned, offers one of the greatest advantages of project finance. This keeps all of the project-related financial risks off the parent companies' balance sheets, and also allows the SPV to borrow the required funds depending on the project's own financial viability, regardless of the existing financial situation of the parent companies.

5.3.2 FUNDING SOURCES

This section describes the various funding sources that are used to fund PPP projects. Urban PPP projects are capital-intensive and require a large amount of funds for the project to be procured. There are different funding sources and mechanisms that the project partners can consult to secure funding for the projects. They include public and private funds, as well as a mixture of debt and equity, as discussed in greater depth in the following section.

5.3.2.1 Public vs. Private Funds

Both public and private entities combine to provide funds for PPP projects. They both invest in different capacities and with different purposes. While the private sector's main purpose is to generate attractive revenues, the public sector aims to achieve the best value for money. The following section provides a brief description of the public and private funds used in a PPP project.

5.3.2.1.1 Public Funds

The involvement of the public sector in funding PPP projects depends mainly on its role in the partnership and on the contract type. The government may choose to fund the project in its entirety and utilize the private sector's expertise in the project procurement. This could be the case in contract types in which the private partner is not required to provide financing for the project, such as a DBFOM, and a BOT.

In other cases, the public sector will require the private partner to provide all or part of the funding for the project; however, it still contributes to the funding process. One way this can be done is through offering grants to the private entity, and can be either in-kind or in cash. Grants are often accompanied by several conditions that must be met before the project receives funding, and some of those are related to the amount of equity that a partner contributes to the project. Another option in which the public sector could get involved in the funding of PPPs could be through loans, in which the government offers lower than the market interest rates on loans. This is true for private activity bonds (PABs), which are bonds issued by governments to support private investments (FHWA, 2015). Equity can also be provided by the government, in which it helps fund a shortfall that the private partner may need in order to procure a project. Fees, that the private partner would have otherwise been required to pay, can be waived by the government to relieve the private entity from some of the project costs. This money is often paid by the government's own budget, and it is used to remove any demand-related risks from the private sector.

5.3.2.1.2 Private Funds

The private sector, apart from the private partner in the PPP agreement, also contributes to the funding of the project. The involvement of the private sector is mainly in the form of private lenders, who loan the project funds that it expects to be repaid after a certain period of time. The main lenders to a PPP project are commercial banks, institutional investors, bondholders, and, as previously identified, the host government. Commercial banks have emerged as the preferred source of debt for PPP projects, mainly due to their willingness to fund long-term projects, and their flexibility in renegotiating the loan terms during the project life-cycle. Institutional investors, such as pension funds, investment banks, and insurance companies, also invest in PPP projects. They either provide direct loans to the project, or they resort to purchasing project bonds. Both commercial banks and institutional investors may also prefer to act as equity investors to a project if they are willing to accept higher risks in return for higher rewards.

5.3.2.2 Debt vs. Equity

The primary forms of funding PPP projects are debt (senior and subordinated) and equity. Each project differs in the amount of funding that is received from each source, but commonalities can be found among all projects. The following section will further detail the instruments that the previously discussed public and private funds are put into to fund PPP projects.

5.3.2.2.1 Debt

As previously indicated, the main debt lenders to PPP projects are commercial entities such as banks, insurance companies, and pension funds. Commonly, commercial banks offer long term loans to the project company, while insurance companies and pension funds purchase project bonds. Governments also take part in the debt financing of PPP projects through offering loans or purchasing project bonds. Regardless of the financing mechanism, the debt can be classified as either senior or subordinated, that is, they differ in the priority of repayment. Senior debt has priority over all types of debt in terms of repayment, while subordinated debt, or mezzanine debt, is at a junior position. Therefore, it is common for mezzanine debt lenders to require higher rates of return, due to their acceptance of a higher default risk. However, both senior and subordinated debts have a higher repayment priority than equity investors.

The decision whether to lend to a project, and how much to lend, depends on the project company's credit-worthiness, if the project is not structured as project finance, and on the project's own cash flows and inherent risks. Lenders will seek assurances from the project company that the project can generate enough revenues to repay the debt; therefore, lenders require the project company to invest a certain amount of equity into the project. The proportion of debt that makes up the total project funding varies from one project to another, but it is commonly more than half of the total funds. A common measure that lenders will use to assess how much to invest in a project is the annual debt service cover ratio (ADSCR). The ADSCR is used to measure the project company's ability to repay its debts by looking at the net income of the project. In general, the ADSCR is represented as a ratio of net operating income to total debt service, and an ADSCR greater than 1 means that the project entity is able to repay its debts from the project's operating income.

The size of the project can help determine the number of lenders as there could be more than one debt provider to the project. For example, a group of banks may combine their resources to fund a certain project, and they will be referred to as a syndicate. The banks will look at forming a syndicate to pool together their resources as well as sharing the risks among them.

5.3.2.2.2 Equity

Equity investors, such as the private entity project sponsors, commercial lenders, or governments, seek to purchase shares in the SPV in order to provide funding for PPP projects, in exchange for ownership of the SPV. Structuring the equity in a PPP is important to ensure proper risk allocation and profit-sharing mechanisms. Moreover, the presence of equity in the project's financial structure sends a message to lenders that the project's shareholders have belief in its ability to succeed.

One main drawback of investing in equity is that it is expensive. Equity is at the lowest position in terms of repayment; therefore, the return rate on equity that is required by investors is usually higher than that of debt lenders. Furthermore, equity investors bear the highest amount of risk among project stakeholders, due to their position at the bottom of the repayment hierarchy.

Companies are often faced with the decision on how much debt to acquire for a project, and how much equity to invest. Several benchmarks are used to describe the trend of how much to invest in debt versus equity; and one of the most commonly used ratios is the debt to equity ratio (D/E), described further in another section (best to list the section for reference purposes) in this Thesis. For large-scale capital-intensive projects associated with high costs, the proportion of debt used is generally much higher than that of equity.

6. PROJECT CASH FLOW

One of the core efforts in determining the viability of a PPP project is assessing the project's costs and revenues streams. In most PPP arrangements, the private partner will be involved in the construction of the facility, while also taking over operations and maintenance. In analyzing the costs and revenues of a project, several analysis techniques are usually employed. First, the costs and revenues need to be determined, then the viability of the project is determined using a discount rate and determining the Net Present Value (NPV) of the project. The project's life-cycle is usually analyzed in two different stages: the construction phase and the operations phase, and the different costs and revenues are determined for each phase according to the classifications discussed as follows.

6.1 Costs

The costs in PPP projects are not dissimilar to those of other infrastructure projects. The responsibilities of each partner in either of the two phases depend heavily on the contract signed and the type of PPP chosen. However, regardless of the responsibilities agreed upon, each stage has costs that one of the two parties will have to cover. In the construction phase, the general costs of building the infrastructure need to be taken into account. In this phase, several aspects can be contracted out to subcontractors. It is typical to find subcontractors who are responsible for the construction of the facility, along with handling procurement costs. Such activities could include construction, procuring and setting up toll gantries, as well as any other necessary infrastructure work.

Different types of costs are incurred during the procurement of an infrastructure project. These costs can be grouped into categories, and after their identification, e the costs can be measured or estimated, analyzed, and possibly reduced. The different cost types that could be realized during a project include:

- Life-cycle costs
- Future and opportunity costs
- Direct, indirect, and overhead costs
- Fixed and variable costs

Categorizing costs is useful when analyzing the different costs to extract information in order to potentially lower the costs A brief description of the different costs types is provided below according to a review of (World Bank; ADB; IDB, 2014; Delmon, 2010; Savas E. , 2000; Grimsey & Lewis, 2004; Engel, Fischer, & Galetovic, 2014)..

6.1.1 LIFE-CYCLE COSTS

Costs are expected to arise during the different stages of a project, and the life-cycle costs are simply the summation of all the costs that occur from the project's initiation until its closure. The different life-cycle costs that are typical and common among infrastructure projects include initial investment costs, operating and maintenance costs, and disposal costs. These costs are subdivided according to the specific time periods associated with the project's life cycle.

The initial investment costs include the investment costs, preparation, fabrication, transportation of construction materials, equipment, and project site offices,, and other relevant initial expenditures that take place at the onset of the project and during the construction phase.

The operating and maintenance costs occur during the lifetime of the project, after initial construction and before possible disposal. The costs are all those that are necessary to operate and maintain the infrastructure during its lifetime, and include personnel costs, payments to subcontractors, depreciation, insurance, debt service, and taxes.

Disposal costs are those that occur at the end of the project's life cycle, and they include the costs of removing equipment, and any costs related to the transfer of ownership. At the end of the project, there might also be a salvage value, which could be recovered from the removal, sale or scrapping of certain equipment or land.

6.1.2 FUTURE AND OPPORTUNITY

Other costs that are difficult to include in one of the three life-cycle cost categories include future and opportunity. Future costs might be due to the replacement of equipment future operating and maintenance costs and disposal costs that may arise during the project's lifetime. Also, since there is an investment involved in infrastructure procurement, which means there is an opportunity cost to that investment. When an investment decision is involved it means another investment is forgone, and the opportunity cost is the cost of forgoing that other investment in order to pursue the current one.

6.1.3 DIFFERENT COST CLASSIFICATIONS

While it is most common to classify costs in PPP projects depending on what stage of the life-cycle they occur, there are other classification methods available. Two common ways these are classified are direct or indirect, and whether fixed or variable.

6.1.3.1 Direct, Indirect, and Overhead Costs

Costs could also be attributed to a specific cause, regardless of when they occur during a project's life-cycle; these costs are referred to as direct costs. While direct costs could be assigned to a specific operation, there are also indirect costs that cannot easily be allocated to a specific operation. Examples of direct costs include cost of materials, labor, and production-related expenses. On the other hand, examples of indirect costs include depreciation and administrative expenses. Moreover, a third cost description is referred to as overhead costs, which also cannot be attributed to a specific operation, but are ongoing business costs. Overhead represents all business expenses that are not related to direct labor or direct materials, and might include rent, utilities, and insurance. Overhead costs can be fixed or variable, as discussed further in the following section. Overhead costs are necessary for budgeting and profitability study purposes.

6.1.3.2 Fixed and Variable Costs

Another classification of costs that makes cost analysis more beneficial, is segmenting based on fixed versus variable costs. Both fixed and variable costs can be direct, indirect, or overhead costs. Fixed costs are those that do not change during the project's life cycle, and remain constant regardless of the work performed. Such costs may include administrative salaries, property taxes, insurance, and capital costs. On the other hand, there are costs that do change with the amount of work performed, and they vary depending on the project's operation. Such costs may include costs of direct material and direct labor. The study of fixed vs. variable costs will help the decision makers understand the profitability of increased production by knowing at what point the project will break even. This is done by using breakeven analysis, which measures how many units must be sold to cover a project's fixed costs, according to Equation 6.1 below.

$$Breakeven\ Volume = \frac{fixed\ costs}{revenue\ per\ unit - variable\ cost\ per\ output} \tag{6.1}$$

For example, on a highway toll-road project, it will be important to understand the breakeven traffic volume needed to cover the fixed costs of the project. The variable costs per output shown in Equation 6.1 will refer to costs that would increase if more vehicles use the facility, such as maintenance costs. The revenue per unit is the toll revenue that is collected per vehicle. The fixed costs refer to all the costs that do not change if more vehicles use the facility, such as administrative salaries and financing costs. Another point that should be made for the purpose of clarification is that the concept of "fixed" is relative, meaning that small changes or fluctuations could still be observed even if a cost is classified as "fixed." For example, while administrative salaries might increase during the project lifecycle due to staff getting promoted, those effects will only have a small variation on the overall administrative salaries, and they are independent of the work output.

6.2 Revenues

The revenues from PPP projects depend heavily on the type of contract, and as mentioned in the previous section, the type of PPP arrangement dictates the revenue streams that the private entity will receive from the government body. It is common to receive revenues from one of two sources: from the public entity or from the users directly. In the former, the revenues are either pre-determined in the contract and paid as a lump sum, or are based on the performance of the private partner, and are considered as availability payments. On the other hand, the private entity can also receive revenues from the users of the facility or service directly. The types of revenues also differ by sector, and in some cases, it is not possible to charge users for a service or a facility usage. The following discussion presents the differences between a user fee and a fee paid by the government.

6.2.1 USER-BASED

In some cases, the users of a service or facility will be required to pay an extra amount in return for improved services. One example is a toll paid by the user is a toll-road. While there is a general hesitation towards accepting tolls, charging users for services has been growing in recent times. The fees that the users are charged have traditionally been established in the contract, as the public entity wants to ensure that taxpayers are not being priced out of using a certain facility or service. Also, the contract duration will be impacted by the fact that the private partner is receiving fees from users, in which the length of the contract should be set to allow the private operator to generate a return on the investment. Finally, with a user-based fee model, the private partner will assume all demand-related risk on the project.

6.2.2 Government-Based

As opposed to the user-based fee concept, the private partner may receive its revenues from the government. This revenue model is generally more common than a user-based fee, in which governments generally enter into contracts with the private sector promising payments depending on the availability of the facility. This form of payment is commonly referred to as availability payment, and it can be found across all urban infrastructure sectors. As such, with this arrangement, the public authority shoulders demand-related risks.

6.2.3 Indirect Revenues: Economic Impact

After determining the costs and revenues over the lifetime of the project, they are discounted using a pre-determined discount rate. If the NPV is calculated to be greater than or equal to zero, then the project would make sense financially. However, if several projects are to be assessed, and only one must be chosen, then the project with the highest NPV must be chosen (Cruz & Marquez, 2013; Asian Development Bank, 2010).

Some projects also lead to revenues being generated, but are not directly collected by the project developers, and sometimes cannot be specifically attributed to the project at hand. Nevertheless, the emergence of a project in an urban setting can bring benefits to the community, without appearing on the SPV's financial statements. In calculating a project's financial viability, these revenues need to be accounted for, especially by the public sector, because in some cases, if a PPP arrangement were not used, the project would not have been procured at all (Cruz & Marquez, 2013; Asian Development Bank, 2010).

Some examples of indirect revenues that may occur due to a PPP project in an urban area mainly include sales of land and area development. If, for example, a school or a public transit terminal was built in a certain area, and housing growth in that area increased thereafter, then the revenues generated to land owners and the government could be attributed, in part, to this project. Moreover, if the project were procured under a PPP arrangement, with the PPP being the only available option at the time, then this would be an example of indirect revenues being generated as a result of a PPP project (Asian Development Bank, 2010).

In addition, the private sector could also realize indirect revenues from participating in a PPP arrangement. If, for example, a private partner is awarded a contract for a large-scale project, and having that project as part of its portfolio enhances its reputation, then it could help the private partner in securing future jobs. This could be attributed as indirect revenue for PPPs, when considering that the project would not have been procured under traditional methods.

Even though it may be difficult to quantify indirect revenues, and to directly attribute them to a single project, they could present a notable advantage of a PPP project. In assessing the financial viability of a PPP project, the quantification and inclusion of the indirect revenues could provide a better picture of a project's profitability.

This chapter provided an overview of the project cash flow for a PPP project. The different elements necessary to study the project cash flow and, ultimately, the financial viability of a project. Revenue and cost components were discussed in detail, and were identified for use in future sections of this Thesis after they are adjusted for risk. The following chapter will detail the risk management procedure described in the methodological framework of this thesis, and will serve as a method to adjust the revenue and cost components presented in this chapter based on their risk exposure in order to construct a more accurate risk-adjusted cash flow.

7. RISK

Risk is the possible occurrence of an event that has positive or negative impacts on a project. There are different ways to classify risks on a project; however, regardless of their classification, common risk elements need to be evaluated when assessing risks according to Kliem and Luden (1997), and are listed as follows:

- Probability of occurrence
- Frequency of occurrence
- Impact of occurrence
- Importance relative to other risks

These elements are important in identifying, analyzing, controlling, and reporting risks. However, measuring each of these elements is not simple; several techniques have been developed in order to arrive at an estimate of the effects of risks and in turn support effective risk management (Kliem & Ludin, 1997).

Risk management is essential to the success of a project. Managing risks involves several different steps, including risk identification, risk analysis, risk control and risk reporting (Kliem & Ludin, 1997; Heinze, 1996).

7.1 Risks in PPPs

As part of a PPP structure, risks are also related to the uncertainty of outcomes. In a PPP agreement, there exists a risk of failure to realize an outcome, which could be related to the delivery of the project on time or the realization of acceptable revenues, meaning that there is a cost associated with risks in PPP projects. Therefore, in such cases, the nature of a PPP, which allows the transfer of risks from one party to the other, determines who will be responsible for these risk costs.

Public-private partnerships offer the advantage of transferring risks from one party to the other, mainly from the public to the private partner, to be better able to execute a project (Akintoye, Hardcastle, & Beck, 2003). Risk sharing is an essential component of structuring a PPP agreement, as it can be the difference between a successful and a failed project (Jin & Doloi, 2008). In fact, risk allocation and sharing was identified as one of the most important factors that contribute to the success of a PPP project (Ke, Wang, & Chan, 2010). Currently, large infrastructure projects experience significant under-management of risks during all stages of the project life cycle. According to a report published by McKinsey & Company in 2013, “direct value losses due to under-management of risks for today’s pipeline of large-scale projects may exceed $1.5 trillion in the next five years, not to mention the loss in GDP growth as well as reputational and societal effects.”

In general, the public entity will look to transfer risks that it is not able to handle to its private partner, but governments must not attempt to transfer too much risk to the private partner (Cangiano, Hemming, & Ter-Minassian, 2004). One reason for that is if the private partner assumes too much risk but is not prepared or equipped to handle the risk, the success of the project may be jeopardized. Another reason is if the government expects the private partner to assume too much risk, then it risks losing potential investors in the future.

7.2 Risk Identification

One of the most important tasks in managing risks is risk identification, as a failure to realize the existence of a risk is detrimental to a project’s outcomes (McKinsey, 2013).

Effective risk management involves initially identifying risk. Despite its importance early on in the project life cycle, it should be an ongoing process until the end of the project (McKinsey, 2013; Akintoye, Hardcastle, & Beck, 2003).

Since there are different risks associated with PPP agreements, various general methods have been used to classify those risks. Some of the classifications are listed as follows (Cangiano, Hemming, & Ter-Minassian, 2004; Hall, 1998; Grimsey & Lewis, 2002; Ng & Loosemore, 2007; Pantelias, 2009):

- Acceptable vs. non-acceptable,
- Short-term vs. long-term,
- Positive vs. negative,
- Manageable vs. non-manageable, and
- Internal vs. external
- General/Country vs. Project-specific
- Development vs. Construction vs. Operation vs. Ongoing

Risks are not always strictly classified according to one of these methods; their classification could involve more than one of the listed methods. The various risks common to PPP projects are briefly discussed as follows (Yescombe, 2007; Hardcastle & Boothroyd, 2003; World Bank, 2014; Infrastructure Australia, 2008).

7.2.1 Construction Risk

The cost of constructing a facility is a main determinant of the financial viability of a project, in which uncertainty around its outcome can affect the investment decision.

Managers attempt to address anticipated price escalations to make sure the cost of completion is in line with the anticipated budget. Cost overruns can severely impact the project's financial stature, resulting in increased debt ratios, which will in turn alert future lenders and could cause the cost of borrowing to increase.

In addition to cost overruns, construction risk is also present due to delays and substandard performance, both of which contribute to prolonging the construction phase, and delaying revenue streams for the private company.

7.2.2 INVESTMENT RISK: DEMAND, REVENUE, AND MAINTENANCE RISKS

Investment risk is a term referring to demand, revenue, and maintenance risks, all of which affect each other, and affect the investment in the project. These risks are particular to the operations phase of the PPP, during which the project company receives the majority of its revenues. Therefore, it is a type of financial risk, and failures resulting from lower than expected demand and revenue could negatively affect the project's financial viability. Also, considering that any maintenance will have an effect on roadway conditions which in turn affects the users' propensity to travel on the roadway and eventually revenues, this risk is also a type of engineering risk. Other terms that are used to refer to risks occurring during the operations phase include usage, network, revenue payment, availability, and maintenance. These risks are all part of the investment risk definition that is used in this Thesis; they all interact with each other and collectively affect the project's profitability.

Investment risk incorporates a number of the most common risks that PPP projects face. Demand is one of the greatest uncertainties when assessing a project's financial viability, and the variability associated with the demand of a service can have great effects on both the private and public entities (Kwak, Chih, & Ibbs, 2009). Moreover, demand is the direct contributor to the private party's revenues in a user-based revenue structure, in which the private entity generates its revenues by collecting fees from the users of the facility directly. Therefore, changes in demand forecasts will results in changes to the project's revenues and, thus, the viability of the project. For this reason, demand and revenue risks are discussed as part of the investment risk of a PPP.

7.2.3 POLITICAL AND LEGISLATIVE RISKS

Changes to legislation that will affect the terms of the PPP agreement and impact profit are referred to as legislative risks. The host government could impose tax increases, for example, that would heavily disrupt a project's cash flow, highlighting one aspect of the political risks that a PPP project could face. Also, legal restrictions could be applied that would reduce a project's ability to operate efficiently. Additionally, changing the terms of a project could have a great impact on its operations. For example, if previously toll increases were frozen, then the private partner would not be able to achieve its revenue goal it was expecting as part of the past forecasts. Another example could be allowing competition, such as an adjacent non-tolled or with lower toll rates, to operate and impact demand and consequently revenue streams. Host governments can also cancel projects or oppose them entirely, directly affecting the profitability of a project.

7.2.4 SITE-SPECIFIC RISKS

Multiple risks are associated with the project site itself, and they are more likely to occur early on in the PPP life-cycle. These risks are usually allocated to the public or private sector, or are even shared between the two. Some common issues that may arise include those related to permits, site geology, and environmental clearance issues, discovery of endangered plant or animal species, discovery of archaeologic or historic sites, rights of way acquisition, and drainage easements. Any of these factors can cause significant delays to projects, which is associated with high costs. Moreover, the inability to acquire a site or a permit to move forward with the project can even lead to the project being shut down altogether.

7.2.5 OPERATING RISKS

The operations phase of a PPP is a lengthy one, and in certain cases, it is the only phase in which private partners receive revenues. Therefore, disruptions in operating activities can have a severe impact on the project's cash flow. Efficiency reductions during the operations phase, such as equipment malfunctions, damage to infrastructure components, crashes that close portions or all of a highway for a period of hours or days, can disrupt revenue streams, in the energy, telecommunications, and/or transportation sectors, for example. Projects are required to operate at a certain level of efficiency for services to be provided or for products to be produced. As a result, inefficiencies can disrupt a project's revenue streams, and affect the profitability of a PPP.

7.2.6 Economic and Financial Risks

Lenders are major stakeholders in PPP projects as loans provide the majority of funding. As a result, one major payment that the borrower has to pay is interest payments to the lenders. The amount being paid is heavily affected by the market interest rates, if the loan is charged at a floating, or variable, interest rate. Therefore, fluctuations in the market interest rate will have a great effect on the cost component of a project's cash flows, and can ultimately affect a project's financial viability.

As with the interest risk, changes in currency rates could also pose a challenge to PPP stakeholders. Financing could be raised by foreign investors in their own currency, but revenues will remain in the local currency. As a result, in project finance PPPs, the borrower will have to go through the foreign exchange market (forex) to pay the lenders.

Furthermore, a project could be impacted by economic factors, depending on the specific industry to which it is related. Changes in demand and supply, and pricing of raw materials, commodities, and/or products could affect the private entities ability to service its debt. In some cases, private partners in PPPs operate at a small profit margin- which increases the effect of such economic changes on the profitability of a project.

7.2.7 Force Majeure Risks

A force majeure event could be internal to the project or external, but both would have an effect on its profitability. Events that are specific to a project include fires, technical failures, or strikes. These events are usually out of the control of the private partner, but would affect operations. Additionally, external events could occur and would also affect the project, such as earthquakes or revolts. In some instances project lenders or governments could help the private partner by providing contract extensions to recover revenues or allowing late repayments of debt.

The allocation of risks to the different parties commonly occurs after the risk identification stage and could be performed before, or after, risks are carefully assessed (Kwak, Chih, & Ibbs, 2009). The following section provides a discussion on risk assessment, its importance in risk management, and techniques to assess risks.

7.3 Risk Assessment

After identifying the risks that could potentially occur during a project's life cycle, the risks should be carefully assessed in order to be properly managed. Risk assessment and quantification could indeed prove to be the most challenging part of managing the risks of a PPP project. This is due to the various uncertainties associated with such projects, resulting in the need to consider a range of possibilities in a probabilistic study of risk. As opposed to a deterministic analysis, a probabilistic formulation will consider a range of possibilities that might occur, and would also give out a range of possible answers to the analyst (Koller, 1999).

There has been substantial research on risk assessment techniques, especially those that take into consideration a range of values instead of discrete, single-valued possibilities. Some techniques have not been studied extensively in the assessment of risk in infrastructure, but have been more common in other fields such as finance, whereas others have been more commonly studied in the context of infrastructure risk assessment. Some of the risk assessment techniques that have been studied, not only in infrastructure risk management but also across various other fields, include:

- Bayesian Analysis
- Decision Trees
- Monte Carlo Simulation
- Method of Moments
- Artificial Networks
- Value at Risk

These risk assessment methods represent different options for quantitatively analyzing risks in PPP projects, in order to mitigate unexpected costs and complications that may occur during the project's life cycle. The author recommends performing sensitivity analysis prior to using any of the identified risk assessment methods. The purpose of the sensitivity analysis is to identify which risk factors among the list prepared in the risk identification step have a significant impact on the financial viability decision. As a result, only those sensitive risk variables will be examined in the risk assessment stage. Table 7.1 presents a brief overview of the literature on the work done on these risk assessment methods (Haimes, Li, & Tulsiani, 1990; Chua, Kog, Loh, & Jaselskis, 1997; Boussabaine & Kaka, 1998; Dey & Ogunlana, 2001; Chau, 1995; Songer, Dickermann, & Pescsok, 1997; Yuwen & Zhang, 2013; Zhang & Damnjanovic, 2006) (Han, Stone, & Zhang, 2014; Zhang & Damnjanovic, 2006; Mishra, Khasnabis, & Swain, 2015; Grimsey & Lewis, 2002; Jin & Zhang, 2011; Chang T. , 2011; Pantelias & Zhang, 2010) (Khan, 2013; Bouejla, Chaze, Guarnieri, & Napoli, 2014; Boussabaine A. , 2014). A brief description of the different methods is then presented below to highlight their strengths, weaknesses, and limitations in assessing project risks.

Table 7.1 Overview of Research into the Presented Risk Methods

Method	Authors	Topic
Monte Carlo Simulation	Grimsey & Lewis, 2002	Risk analysis on urban water treatment project in Scotland
	Dey & Ogunlana, 2001	Project time risk analysis through simulation
	Songer et. al, 1997	Project cash flow in toll road project
	Chau, 1995	Distribution form for cost estimate
	Yuwen & Zhang, 2013	Estimating overall project risks for a toll road project
Decision Tree	Haimes et. al, 1990	Multi-objective decision tree
	Chua et. al, 1997	Development of budget performance model
Neural Networks		
	Jin and Zhang, 2011	Modeling optimal risk allocation in PPP projects using artificial neural networks
	Chang, 2011	Study for digital game content stocks price prediction
Method of Moments	Han, Stone, and Zhang 2014	Optimizing pavement preventive maintenance cycles
	Zhang and Damnjanovic, 2006	Quantifying the risk cost associated with warranty specifications for transportation infrastructure
	Zhang and Damnjanovic, 2006	Modeling reliability of pavements infrastructure
	Pantelias and Zhang, 2009	Measuring investment risk in PPP projects
Bayesian Analysis	(Khan, 2013)	Risk factors in toll road life cycle analysis
	(Bouejla, Chaze, Guarnieri, & Napoli, 2014)	Manage Risks of Maritime Piracy against Offshore Oil Fields
	(Xie & Ng, 2013)	Multi-objective Model for Public-Private Partnership Decision Support
	Boussabaine, 2014	Risk pricing strategies for public-private partnership projects
Value at Risk	Mishra, Khasnabis, and Swain (2015)	Incorporating uncertainty and risk in transportation investment decision-making

7.3.1 BAYESIAN ANALYSIS

Bayesian Analysis provides a method of assessing and quantifying risks using probabilities. Its underlying principle is based on updating existing information with new information once it becomes available in order to make better-informed decisions, making it a powerful risk assessment tool (Koller, 1999; Bedford & Cooke, 2001; Stone, 2013; Haimes, 1998).

Bayesian analysis requires the establishment of initial probabilities of occurrence, which will be updated once new information is available. The initial probabilities are established by gathering data from different sources, and combining the data sets to produce a generic data set that could be presented in the form of success or failure rates. Updating the data usually involves consulting with subject matter experts, recognizing their importance in the decision-making process. The input from the subject matter experts to the analysis process makes Bayesian analysis a popular method.

One example that illustrates how Bayesian analysis is performed is in measuring the site-specific risks. Prior to receiving access to the site and being allowed to drill and discover its geologic features, there is limited knowledge of the risks. Such risks could include, as specified earlier, the issuance of permits, the ground condition, environmental issues, and archaeological risks. Therefore, at the onset of the project, the probability of occurrence of each will be assigned based on nearby site data and historical data, and will be updated once more information becomes available.

Dollar values can be assigned to the analysis in order to understand the total project costs. For example, if the current total project costs are estimated at $1 million, and there is 30% a risk that the authorities will not approve the project design, but will require the designer to add features costing an additional $200,000, this risk cost will be taken into account when estimating the total project cost. The expected value of the total project risk cost, therefore, will be calculated by multiplying each value with its probability of occurrence, in which the risk of a higher cost will be factored in. That is, the expected value of the total project cost is shown in Equation 7.1 below.

$$EV(Total\ Cost) = 0.7 * \$1\ million + 0.3 * \$1.2\ million = \$1.06\ million \qquad (7.1)$$

Equation 7.1 shows that the expected value of the project increases from $1 million to $1.06 million, which means that the total risk cost of the project is estimated to be $60,000. Figure 7.1 illustrates this example in a graphical format.

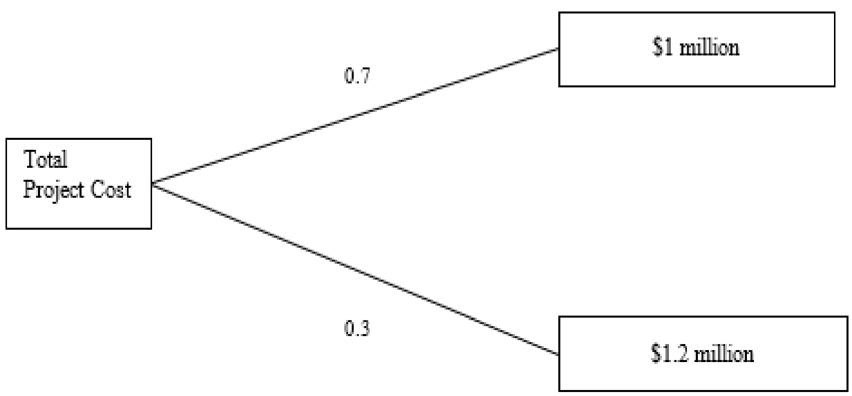

Figure 7.1 Example of Bayesian Analysis

Bayesian analysis is a powerful business and planning tool due to its reliance on historical information and allowing the easy incorporation of new data into the analysis. It has also provided a platform for other assessment methodologies, such as decision trees, as will be described in the following section. One of the main drawbacks of Bayesian analysis is the subjectivity that is involved when consulting subject matter experts to obtain probabilities of occurrence of certain events. Restricting the information sources to historical data from past projects could mitigate this issue; however, in some cases, such historical data might not be available, and subject matter experts will be the best source of information. In addition, the use of such a form of Bayesian Analysis is best suited to sequential risks, in which a future outcome depends on the outcome of a prior event. This is also true for decision trees which will be discussed in the next section.

7.3.2 DECISION TREES

Decision analysis plays an important role in analyzing quantitative risk, and the use of decision trees offers a practical approach to organizing a decision problem with a finite set of actions. It is one of the most commonly used tools in risk-based decision making, mainly due to its reliance on a combination of graphic and analytic presentations. The graphical part is descriptive, while the analytical part builds on Bayes' theorem. **Error! eference source not found.** presents a generic decision tree, and its main components are further described afterwards (Koller, 1999; Damodaran, 2008; Haimes, 1998)**.**

The main parts of a decision tree include the decisions that need to be investigated, the alternatives present, the probability of occurrence of each alternative, and the consequences of choosing each option. These components will be described by using an example of choosing a project delivery method, with the objective of achieving the best net present value (NPV) and earning the highest profits.

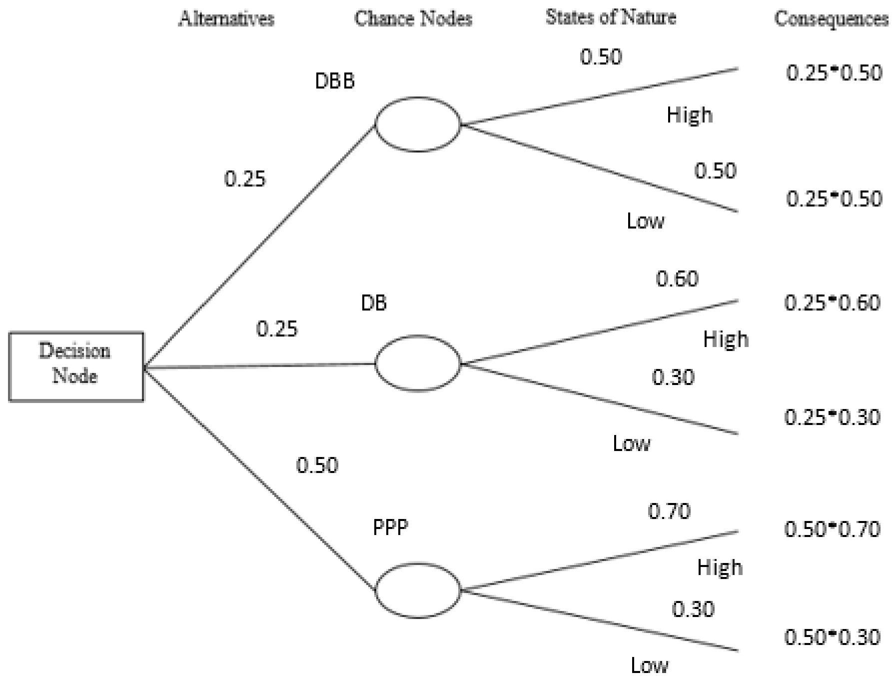

Figure 7.2 Example of Decision Tree

Decision node: A decision node represents the various decisions that the decision maker is faced with, in this case, what project delivery method to choose. Attached to it are the different available alternatives, such as DBB or PPP in this case.

Chance node: The chance nodes represent the states of nature of each alternative, along with their probabilities of occurrence. For example, a DBB would have a 50 percent chance of achieving an NPV that is "low" and a 50 percent chance of a "high" NPV. The PPP alternative, on the other hand, has a 30 percent chance of achieving a "low" NPV, and a 70 percent chance of a "high" NPV.

Consequence node: The consequence of each alternative is then calculated based on the chance probabilities assigned earlier. Therefore, the consequence of each alternative could be represented as the profit that could be generated from each alternative.

As can also be noticed from this example, decision trees offer a solution to analyzing sequential risks. The choice of project delivery method is made before the project realizes revenues and costs, and before the NPV is calculated.. For these reasons, the use of decision trees is popular among decision makers, as it offers a flexible but powerful method to risk analysis, planning, and mitigation. Moreover, its reliance on the Bayes theorem of using prior probabilities to calculate future ones, while being able to update the prior probabilities once new information becomes available, adds to its benefits.

In some cases; the use of decision trees could prove problematic if the risks are not sequential and cannot be discretized. This is a problem for a large number of risk factors that do not occur sequentially, and the use of decision trees should be avoided in such cases. For example, a decision tree is not suited for risks that might take on a continuous spectrum of outcomes. For these types of analyses, a simulation approach to risk assessment would be a better option, as discussed in the following section.

7.3.3 MONTE CARLO SIMULATION

Monte Carlo Simulation (MCS) is a sampling technique that uses the generation of random numbers to determine the values of uncertain variables in decision-making situations. When a problem is formulated and stochastic variables are identified, MCS is used to generate random numbers for these variables based on certain defined distributions. MCS It is used as an alternative to the previously discussed decision tree method for making decisions.

In an MCS approach, a mathematical model or equation is constructed that describes the relationship among the stochastic variables and the decision under consideration. Next, for each stochastic variable, possible values of occurrence are determined, along with the expected value, standard deviation, and the form of the distribution. The mathematical model and the distributions of the stochastic variables form the input for the MCS. For each variable, random numbers are generated according to the defined distributions. After each simulation, which includes the random number generation of each uncertain variable, a value for the decision is obtained. After thousands of simulations, a profile describing the variation of the decision is plotted.

As previously indicated, MCS uses a distribution of possible inputs to randomly generate a range of outputs. One example that illustrates the MSC methodology is a simplified case of estimating the profits of an investment. The profits are calculated based on the profit equation, whereby costs are deducted from revenues, and both costs and revenues can take a range of values depending on certain factors. In estimating profits, the revenues and costs need to first be calculated, based on the range of possible values. For example, revenues on a toll-road are dependent primarily on the traffic demand and the toll rate. The traffic demand is an uncertain variable that can take a range of possible values. In this example, it is assumed that the traffic volume has a range of possible outcomes, and an expected mean value. It is also assumed that it is normally distributed. In an MSC random numbers for traffic volume are generated based on the distribution, and the total profits will change once each random number is generated. Similarly, this procedure is replicated simultaneously for each uncertain variable that influences the costs and revenues. After thousands of concurrent simulations of the uncertain variables, and using the profit equation, a distribution of profit values will be obtained and can be analyzed to understand the risk profile of the decision under consideration. This enables the decision makers to make better-informed decisions based on the amount of risk they are willing to accept.

One of the main advantages of Monte Carlo Simulation is the ability to model a wide range of possible values using a variety of distributions. This helps incorporate a more realistic view on the variations in risk parameters, enabling more informed decision-making. Another advantage is that it offers a probabilistic analysis of risk, in which probabilities are assigned to the numbers that are randomly generated, and the output is also given as a probability distribution. Also, the graphical representation of answers gives Monte Carlo Simulation another advantage. Moreover, Monte Carlo Simulation has the ability to perform a simultaneous analysis of all the uncertain variables under consideration. However, despite such advantages, Monte Carlo Simulation has some disadvantages and limitations. First, its dependence on experts to define distribution models for the variables means that if the experts are incorrect the entire analysis will lead to inaccurate results. Monte Carlo Simulation also requires careful determination of the correlation among the variables that are being studied, or else the analysis of the project's risk profile could be faulty.

With the availability of software that can perform Monte Carlo Simulation in a relatively short period of time, it is recommended that it be incorporated into the decision making process on projects. However, it should be avoided for risk variables that do not have known distributions backed by data. If the distributions are determined by experts subjectively, then the entire Monte Carlo Simulation process could lead to inaccurate estimates of the risk variables (Rezaiea, Amalnika, Gereiea, Ostadib, & Shakhseniaeea, 2007; Munn, 2006; Rubinstein & Kroese, 2008).

7.3.4 ARTIFICIAL NEURAL NETWORKS

An Artificial Neural Network (ANN) is a technology that attempts to uncover valuable information from large amounts of data. It is considered a branch of artificial intelligence, which has the ability to learn certain patterns from inputs and generate outputs. ANNs have the ability to recognize patterns, process signals, and predict outcomes, which is a fundamental task of risk assessment. Therefore, ANNs offer a powerful and flexible tool for risk assessment, which attempts to predict future outcomes by learning available past data and the underlying patterns that exist (Chang M. , 2011; Jin & Zhang, 2011; Koller, 1999) .

The typical structure of an ANN consists of different elements that resemble functioning elements of the human brain's nervous system. As in a brain, there are several neurons that perform processing functions; they receive information from other neurons, process it, and transfer processed information to other neurons. ANN attempts to model this functional element of the brain's nervous system, by constructing processing and transferring elements.

In an ANN, as in the human brain, a neuron-like element receives a weighted piece of information from another similar element, carried through a connecting element. Once the information is received, the neuron-like element combines it with other pieces of information, and based on the resulting weights a signal is fired to another neuron-like node. The signal is fired based on whether the weights, or summed weights, exceed a certain threshold, and as a result, information is passed on to other stages of the system's structure. Another important and challenging task of constructing the ANN structure, in addition to building the artificial neurons, is attempting to understand the interconnections among them. Once these two elements of the ANN are finalized, the system can start its learning procedure, which is one of the main features of an ANN.

ANNs offer a powerful tool to assess risks, by constructing a computer algorithm that can recognize patterns from large data sets to produce meaningful information. The ability of ANNs to learn and adapt to changing circumstances is one of its main features that contribute to its strength. Even though ANNs do not perform probabilistic assessments of risk, their contribution can be beneficial to project managers attempting to study project risks.

One example of how ANNs can be used for risk management on PPP projects is provided by Jin and Zhang (2011). The paper presents a method for optimal risk allocation on PPP projects based on initial data from a survey that was conducted with industry experts, and the ANN models were then trained using this data. The results of the study show that ANNs provide satisfactory results for modelling risks and their optimal allocation. The authors recommended that the PPP partners' risk management mechanism maturity level, their risk management routines, cooperation history, and risk management commitment need to be taken into account as they affect the formation of optimal risk allocation strategies (Jin & Zhang, 2011).

The initial connection weights can be set arbitrarily. One of the great attractions of ANNs is that they are able to learn: the weights can be adjusted automatically from data. To accomplish this, a training set of input data with known answers attached is presented to the network. Over the course of a training session, the connection weights are gradually adjusted by the neural network itself until they reach convergence. If the training set captures the regularities of a wider class of inputs, the trained network will then be able to correctly classify inputs not found in the training set as well. Such a process is an example of supervised learning, in which a teacher (the training set) is used to guide the network in acquiring the necessary knowledge (connection weights).

As previously discussed, the learning capability of ANNs is one of the advantages that the method offers. In addition, the use of ANNs is beneficial when the relationships between the uncertain variables that affect a project decision are not related by a linear equation. Therefore, for decisions in which the relationship among variables is complex, ANNs offer a more viable solution over traditional statistical methods. In addition, the underlying distributions of the variables under study do not need to be known in order to conduct an ANN analysis, as is the case with Monte Carlo Simulation method. However, ANNs are also associated with some disadvantages, one of which is their complexity. Finding the optimal configuration of neural networks for analysis is a time-consuming process that makes it less favorable for assessing risks. Another disadvantage is the lack of interpretability of the weights that are obtained during the model building process. For these reasons, the use of ANNs is best reserved for use among experts who are well acquainted with them, in order to be able to avoid suffering from the disadvantages of this method that would otherwise make it unattractive when time is a constraint, as is most often the case. Also, risks that do not have a certain distribution known to them, and that cannot be modeled through the use of Monte Carlo Simulation, can be modeled using the ANN method (Mukta Paliwal, 2009; Jin & Zhang, 2011).

7.3.5 METHOD OF MOMENTS

Another probabilistic technique for quantifying risks is the method of moments (MOM). It is based on reliability theory, which is concerned with estimating the probability of a system achieving its expected function in a specific time interval. The reliability theory has given rise to the structural reliability problem, which can be found while analyzing the reliability of structures in the field of civil engineering. The main objective of reliability analysis is making sure that the system does not fail, taking into consideration the variables that affect system performance (Damnjanovic, 2006; Zhang & Damnjanovic, 2006; Zhao & Ono, 2001; Pantelias & Zhang, 2010).

As such, a limit state function can be constructed, taking into consideration the stochastic random variables that affect the outcome of the system, identified as *G(X,Y),* where *X* and *Y* represent vectors of random variables that affect the performance of the system. This system, therefore, fails when *G(X, Y)* < 0, and the probability of failure can be identified as $P_{Failure} = \Pr\{G\ (X, Y) < 0\}$. Assuming continuity and independence of the stochastic variables *X* and *Y*, the probability of failure can be estimated as the probability integral of the joint probability density function (PDF) of the variables *X* and *Y*, denoted by $h(X, Y)$, over the failure region of the previously stated limit state function, as follows:

$$P_{Failure} = \Pr\{G\ (X, Y) < 0\} = \int_{G(X,Y)} h(x, y)dxdy \qquad (7.2)$$

The above function can be solved using various techniques: Monte Carlo Simulation, the first order reliability method (FORM), the second order reliability method (SORM), the first order third moment (FOTM) method, and the method of moments. The following discussion will involve the MOM and its guiding principles.

As previously indicated, the MOM is a technique employed to solve multi-dimensional probability integrals, as the one shown in Equation (7.2). In order to do so, two sequential steps are followed. First, the moments of the limit state function are determined, which is done by using point estimates obtained in the standard normal space. Second, the reliability index and the failure probability are calculated using the obtained moments and standardized functions.

Zhao and Ono (2001) have developed a methodology for using the MOM to solve the limit state function of the structural reliability problem presented in Equation (7.2). In order to obtain the higher-order moments of the limit state function, the authors proposed the use of an equivalent linear approximation, as shown below:

$$G'(X,Y) = \sum_{i \epsilon (X \cup Y)} \left(G_i - G_\mu\right) + G_\mu \tag{7.3}$$

Where:

$\boldsymbol{G_i}$ Functions similar to the limit state function, having all variables evaluated at their mean values, except the i^{th} value

$\boldsymbol{G_\mu}$ $G(\mu)$, which is the limit state function evaluated at μ, the mean of the random variables

The reliability index and failure probability discussed in the second step of the process described previously are shown as follows:

$$\beta_{FM} = \frac{3[\alpha_{4G'} - 1]\left[{}^{\mu_{G'}}/_{\sigma_{G*}}\right] + \alpha_{3G'}[\left({}^{\mu_{G'}}/_{\sigma_{G'}}\right)^2 - 1]}{\{\left[9\alpha_{4G'} - 5\alpha_{3G'}^2 - 9\right][\alpha_{4G'} - 1]\}^{0.5}} \tag{7.4}$$

The first four moments of G' presented in the equation can be calculated as follows:

$$\mu_{G'} = \sum_{i=1}^{n} (\mu_i - G_\mu) + G_\mu \tag{7.5}$$

$$\sigma^2{}_{G'} = \sum_{i=1}^{n} \sigma_i^2 \tag{7.6}$$

$$\alpha_{3G}{}'\sigma^3{}_{G'} = \sum_{i=1}^{n} \alpha_{3i}\sigma_i^3 \tag{7.7}$$

$$\alpha_{4G'}\sigma^4{}_{G'} = \sum_{i=1}^{n} \alpha_{4i}\sigma_i^4 + 6\sum_{i=1}^{n-1}\sum\nolimits_{j>1}^{n} \sigma_i^2\sigma_j^2 \tag{7.8}$$

Where μ_i, σ_i, σ_{3i}, and σ_{4i} are the first four moments of G_i (Zhao & Ono, 2001).

Pantelias (2009) provides evidence of the success of the Method of Moments in estimating risk in PPP projects, and particularly, investment risk (Pantelias, 2009). The author used the Method of Moments to obtain a probabilistic estimate of investment risk in PPP projects, by implementing the method on a real-life toll road case study; the previously planned Trans Texas Corridor (TTC-35). The author was able to verify that the different parameter values resulting from the sensitivity analysis and alternative scenarios were successfully investigated, and provided estimates of the investment risk on the project (Pantelias, 2009).

The use of the MOM can be used to solve the structural reliability problem, which is transferable to other problem types, as long as the reliability equation is defined. The MOM is a preferred higher moment statistical method due to the fact that it provides a better estimate of the probability of failure. One of the benefits of the method of moments is that no distribution for the random variables is required, a clear advantage over Monte Carlo Simulation. Another benefit is that it offers a closed-form expression, which does not require an indefinite number of iterations to obtain a solution. In addition, it offers an accurate estimate when the risk equation is presented as a non-linear expression. (Ma, Si, Zhu, & Wang, 2014; Zhang & Damnjanovic, 2006; Zhao & Ono, 2001). Furthermore, the MOM employs a mathematically simple and clear evaluation of the probability of failure (Zhang & Damnjanovic, 2006).

7.3.6 Value at Risk

One of the leading fields in risk management, and particularly risk analysis, is the financial services sector, where there has been much development in quantifying risks. One common risk measure that has been used in financial services is value at risk (VaR). The essential concept of VaR lies in the use of simulation techniques and probability analysis to estimate the worst possible loss that a project or, more commonly in finance, a portfolio can lose in a certain period of time with a specific level of confidence (Jorion, 2000; Crouhy, Galai, & Mark, 2000; Best, 2000; Damodaran, 2003).

One of the advantages of VaR over traditional risk measures is that it measures the effects of risks of certain assets on others. This is an important consideration if the measure is to be transferred and used in the infrastructure sector in which several risk factors must be measured at once. For example, if multiple assets are present in a portfolio then the effects of changes in one asset on another asset can be captured. As a result, if one asset is associated with a risk of change, then the risk of change of the other asset can also be captured. In infrastructure projects the investment risk, as explained earlier, involves demand, maintenance, and toll risks, and the effect of each of these risks on the other needs to be measured, and for this type of problem, VaR can be used. Moreover, VaR has a probability associated with it, making it a probabilistic measurement of risk, giving it an advantage over deterministic risk measures (Best, 2000).

VaR measures the worst possible outcome of an investment, given a certain level of confidence, and a time horizon. For example, a bank can lose a maximum of $1 million in 24 hours given a 95 percent confidence level. The main steps involved in computing the value at risk includes 1) assigning the level of confidence and the time horizon of the analysis 2) assigning a stochastic model that will enable the simulation of random variables for use in the analysis. The main purpose of generating the random variables is to estimate or model the range of possible scenarios that could occur, with the stochastic model assigning the distribution of the simulated variables.

There have been several VaR measurement techniques that have evolved over the years as this measure has gained popularity, particularly in the banking sector. The most common techniques used include the variance-covariance method and simulation (Damodaran, 2003; Best, 2000; Jorion, 2000; Crouhy, Galai, & Mark, 2000).

In the variance-covariance method a probability distribution of potential values is established, and the VaR is then calculated. The method calculates the mean and standard deviation of a portfolio by looking at historical changes, and estimates the VaR. For example, if the price change for a commodity, say gold, was found to follow a normal distribution, with mean of $100 and standard deviation of $10, then, with 95 percent confidence, the VaR would be $80 (two standard deviations below the mean). The procedure becomes more complicated when a portfolio of assets is considered, as the covariance between them needs to be calculated, but the overall principle of estimating a probability distribution and calculating the VaR accordingly remains intact. The main advantage of the variance-covariance method is its simplicity in calculating the VaR, but the normality assumption is one of its main drawbacks (Damodaran, 2003; Best, 2000).

Another alternative to calculating the VaR is through the use of simulation. There are two main simulation techniques used to estimate the VaR: historical simulation and Monte Carlo Simulation. The use of historical simulation offers one of the simplest methods to calculate VaR by using historical data to predict future outcomes. One example to highlight the use of historical simulation is the calculation of oil prices. Historical data of oil prices across 5 years in the past is obtained and graphed. Then, a simulation of future values is determined, assuming these values follow the same distribution as the historical data. Finally, the VaR is calculated by obtaining the 95th percentile value (Best, 2000; Damodaran, 2003; Jorion, 2000) .

Another simulation method of calculating the VaR is Monte Carlo Simulation. The Monte Carlo procedure is performed to generate different values for the risk factors that are under study, with the purpose of estimating the probability of occurrence of certain risks by running a number of simulations using random variables (Best, 2000; Damodaran, 2003; Jorion, 2000). The use of Monte Carlo Simulation is described in a separate section earlier in this chapter. The use of Monte Carlo Simulation to estimate VaR is a recommended method mainly due to the fact that it performs a better job at estimating risks over a longer duration, it is not limited to the assumption of normality, and it can handle the volatility of historical data. However, the use of the variance-covariance method would suffice if the assumption of normality holds and if risk is analyzed over a short period of time. Also, if sufficient historical data is available for risk that does not observe volatile changes, then historical simulation, which only relies on historical data and trends, can also be employed.

The VaR method is also associated with some disadvantages, some of which are similar to that of Monte Carlo Simulation. VaR can lead to false conclusions on risk if the models used in the Monte Carlo Simulation are faulty. Also, VaR has mostly been used in the financial sector to measure short-term risks, which is applicable when analyzing financial or operating risks that involve day-to-day fluctuations. This could be solved through the use of Monte Carlo Simulation, which will improve its effectiveness in measuring long-term risks, but VaR will then experience the same disadvantages as those of Monte Carlo Simulation. In addition, VaR is used to measure the potential losses on a project due to a particular risk factor, without regard to the positive impacts that might be realized if that risk is accepted. Such impacts include obtaining higher returns due to accepting risks or ensuring that the project would not fail if one entity were to assume too much risk. For these reasons, the use of VaR can offer a quick solution to measure risks that might occur in the short term, and should be avoided when long term risks are to be considered, especially since other methods that were previously discussed offer better solutions.

This chapter presented different types of risk assessment techniques, which include Bayesian Analysis, Decision Trees, Monte Carlo Simulation, Artificial Neural Networks, Method of Moments, and Value at Risk. After reviewing the advantages and limitations of each method, it is recommended to cater the risk assessment technique to the problem at hand, as there is not one methodology that is clearly superior to the rest in all facets. Therefore, it is necessary to identify the risks that are inherent in a project before proceeding with the analysis of the risks, in order to be able to select the best approach that fits the types of variable risk factors, the availability of data on the risk factors, the skill set of the analysts, and the required accuracy.

For assessing the risks on a PPP project, the process of quantifying such risks is a complicated task. The uncertainties that are embedded within each variable must be taken into consideration while assessing risks and quantifying them. This makes the risk assessment part of the risk management framework a complicated process. The methods presented earlier provide an overall perspective on the work that has been done in attempting to quantify risks, some of which have been applied in measuring infrastructure and PPP risks. With the knowledge of the risks that are likely to occur in a PPP project, as well as their measured values, the next step of the risk management process involves the mitigation of those risks.

7.4 Risk Mitigation

The final step of the risk management process is risk mitigation. The primary objective of risk mitigation is to reduce the risk of an undesirable event and to decrease the impacts if the event if it does occur (European Investment Bank, 2015). After identifying and quantifying the risks that are applicable to the project, a mitigation strategy should be developed in order to maintain its financial viability. The most common mitigation methods in PPP projects have evolved around three main strategies: retention, transfer, and sharing, all of which revolve around the concept of risk allocation (Jin & Zhang, 2011; Hardcastle & Boothroyd, 2003; Vassallo, 2006). Within each of these strategies, there are additional considerations that can be made; details of these considerations will be discussed further in this section.

7.4.1 RISK ALLOCATION

As previously indicated, the risks in PPPs should be allocated to the party best able to manage them, which is the basic principle in deciding whether to retain, transfer, or share risks. In order to better understand this statement, Irwin, 2007 proposed three considerations that need to be addressed (Irwin, 2007):

1. The ability of the entity to influence the specific risk
2. The ability of the entity to influence the effect of the risk on the project value
3. The ability of the entity to absorb the risk at the lowest cost

The ability of the entity to influence the specific risk depends on the ability of that entity to make decisions that affect that particular risk factor. The decision taken by an entity should affect the outcome of the risk factor, in order for it to be able to bear that risk. One example is that of construction risk; the private entity can influence the schedule, cost, and quality by employing efficient, cost-cutting, and highly sophisticated strategies during the construction phase of the project.

The ability of the entity to influence the effect of the risk on the project value relates to the decision-making authority of an entity in reducing the impact of risks. Some risks cannot be eliminated completely, such as those of natural disasters or environmental risks, but the government could, for example, choose the project location by taking those risks into consideration. As such, the risk would be allocated to the party best able to reduce the negative impact of such a risk occurring.

The ability of the entity to absorb the risk at the lowest cost should be taken into consideration particularly when neither partner can reduce the probability of occurrence of a certain risk. One example is that of market risks, in particular inflation risk. The risk should be allocated to the stakeholder that can best bear the risk at the lowest possible cost-

One common procedure used for risk allocation is the utilization of a risk matrix, in which the identified risks are first listed and then each one of them is assigned to the designated party (Ng & Loosemore, 2007) according to the ability of each party to better handle the risk. A risk matrix is aimed at providing managers in both the public and private sector with a basis for identifying the risks that could occur and their allocation. The risks are allocated to ensure that they can be dealt with at the lowest cost and with the least detrimental consequences to the project's value for money (Grimsey & Lewis, 2004). While there is much disagreement in the literature on how each particular risk is allocated to one party, there is a general consensus on some of the risks. Table 7.2, adopted from (Han, 2013), shows different allocations of risk according to various sources from the literature (Arndt, 1998; VDTF, 2001; Wang, Tiong, Ting, & Ashley, 2000; NTSA, 2004; Li B. , Akintoye, Edwards, & Hardcastle, 2005; Ng & Loosemore, 2007; Lam, Wang, Lee, & Tsang, 2007).

Table 7.2 A Comparison of Risk Allocation Preferences in PPP Projects. Source (Han, 2013)

Risk Factor		**Arndt (1998)**	**Wang and Tiong (2000)**	**VDTF (2001)**	**NTSA (2004)**	**Li et al. (2005)**	**Ng and Loosemore (2007)**	**Lam et al. (2007)**
Political	Termination of concession by government		Public		Public		Public	
	Expropriation and nationalization		Public		Public	Public	Private	
	Political opposition				Public	Public		
	Change in law	Share	Share	Public	Share	Share	Private	Share
	Unstable government					Public		Public
	Project approval and permit	Share		Private			Share	Private
	Influential economic events			Private		Private		
	Changes in industrial code of practices	Share		Private	Share	Private		
Construction	Ability to finance	Private		Private		Private		
	Improper design	Private	Private	Private	Private	Private	Private	Private
	Insolvency of subcontractors	Private	Private		Private	Private		Private
	Quality risk	Private	Private	Private	Private	Private	Private	Private
	Site safety	Private						Private
	Availability of labor/materials		Public			Private		Private
	Ground conditions			Private		Private	Private	Public
	Site availability	Share		Private		Public	Private	Public
	Construction/design changes			Public	Public		Public	Private
	Labor disputes and strikes		Private	Private				Private
	Land use				Public	Public	Public	
	Waste of materials	Private				Private	Private	
	Construction cost overrun	Private	Private	Private	Private	Private	Private	
	Construction completion	Private	Private	Private	Private	Private	Private	
	Supporting utilities risk	Share	Share				Public	
	High financial cost	Private	Private			Private		
	Unproven engineering techniques	Private	Private	Private	Private	Private		

Table 7.2 (Continued)

Risk Factor		Arndt (1998)	Wang and Tiong (2000)	VDTF (2001)	NTSA (2004)	Li et al. (2005)	Ng and Loosemore (2007)	Lam et al. (2007)
	Protection of geological and historical objects		Private	Private				
Operation	Operation cost overrun	Private			Private	Private	Private	
	Operator default	Private	Private	Private			Private	
	Quality of operation	Private	Private	Private	Private		Private	
	High maintenance cost	Private		Private	Private	Private		
	Frequency of maintenance	Private		Private	Private	Private		
	Low operating productivity	Private	Private		Private	Private		
	Residual assets risk	Private		Public	Private			
	Condition of facility	Private	Private					
Legal	Contractual risk	Share						Public
	Third party tort liability					Private		Private
	Ownership assets		Share	Share	Private		Private	
	Insolvency of concession company		Private		Private			
Market	Insufficient income	Private	Private			Private		
	Fluctuation of material cost (by government)		Public	Public	Public		Public	
	Fluctuation of material cost (by private sector)		Private	Private	Private		Private	
	Tariff change		Private	Private	Private	Private	Private	
	Market demand change	Share	Private		Share	Private	Private	
	Exclusivity		Share	Private				
Economic	Inflation risk		Share	Share	Share	Private	Share	Share
	Interest rate		Share		Private	Private	Share	
	Foreign currency exchange rate		Public		Private			
Others	Force majeure	Share		Share	Share	Share	Share	
	Residual risk					Private	Public	
	Weather	Public			Public	Private		Share

The risk matrix is constructed by consulting with experts in the public and private sectors, as well as project lenders. While each of the project stakeholders would prefer a risk allocation that would relieve them of the majority of risks on a project, an allocation mechanism is usually agreed among them and included in the contract.

The allocation of risks in PPP projects is an intensive and critical procedure that is intended to make the most of the benefits of such a project delivery method. The ability to transfer risks from the public to the private entity is often met with an enthusiasm to transfer the majority of the risks. However, if too much risk is transferred, the government could risk losing potential private partners, and will also jeopardize the project's financial viability if not properly allocated. Therefore, the risk allocation process requires an in depth analysis of the specific risk factors in the context of how to choose the partner that is most able to handle such risks. This process is essential to the success of a project, as the failure of either entity in the partnership could lead to the failure of the project as a whole. As a result, this thesis recommends basing the allocation decision on considering three aspects: 1) the ability of the entity to influence the specific risk; 2) the ability of the entity to influence the effect of the risk on the project value; and 3) the ability of the entity to absorb the risk at the lowest cost.

7.4.2 RISK MITIGATION TOOLS

Regardless of the mitigation strategies, there exists a set of tools, mainly adopted from the financial sector that can be used in order to decrease specific risk factors. Examples of such mitigation tools are described in the following sections, including guarantees, letter of credit, bid bonds, performance bonds, surety bonds, insurance, risk premium, and risk-adjusted discount rate. Each tool is usually used by a single stakeholder in the PPP agreement, which could be the public partner, the private partner, or the lenders.

7.4.2.1 Guarantees

The provision of guarantees is made by the government to encourage private investment in public projects by accepting some of the project risks. In some cases, to protect the private entity from demand risk, the public partner may offer guarantees, such as a toll-road revenue guarantee. A toll-road revenue guarantee ensures the private entity will receive a certain, minimum revenue amount in the event that demand falls below a specified level. In the specific case of toll roads, the use of shadow tolls is one way the government can provide a guarantee. With shadow tolls, the private partner is paid by the public entity depending on the number of vehicles operating on the roadway, without actually charging a toll to the roadway user. Another form of guarantee is referred to as availability payments, whereby the government will pay the private entity a fee depending on whether the facility is available for use, regardless of performance specifications (Yescombe, 2007; Akintoye & Beck, 2009).

Additionally, the government may also be able to offer protection from global economic risks in the form of currency exchange rate guarantees, for example. Also, the private partner runs the risk of defaulting on loans, in which case the government may step in and accept the risk in lieu of the private partner by offering loan guarantees. By providing a loan guarantee, the public entity will assume the responsibility of paying the loan back to the lenders.

7.4.2.2 Interest Rate Swaps

One of the major risks that face any PPP project is finance risk. Commercial banks are one of the major lenders to PPP projects which lend on a floating-rate basis, meaning that changes in interest rates could affect the SPV's ability to service its debt. For this reason, hedging instruments have been established in order to mitigate, and even eliminate, interest-related risk. One such instrument is an interest rate swap, which allows the swap of a floating interest rate with a fixed interest rate, and vice versa. In addition, swaps can be made to shift from one floating rate to another. Its main advantage lies in the fact that it allows the SPV to shift the loan from a floating interest rate to a fixed one without having to refinance the bank loan (Finnerty, 2013; Akintoye & Beck, 2009; Fight, 2006).

The principal amount, however, does not change; and the payments will take into consideration the original principal. This essentially shifts the risk of interest rate fluctuations onto the swap partner.

This is best illustrated by an example. Assume that a corporation has agreed to pay its lenders a London Interbank Offered Rate (LIBOR + 1 percent) interest rate on the loan it receives, and enters into a swap with another entity. The swap deal states that the corporation has to pay the swap partner a rate of 5 percent, while receiving LIBOR. In this case, the corporation shifted its floating rate interest loan into a fixed rate interest loan, and would pay a rate of 6 percent. By doing this the corporation shifted the risk of fluctuating interest rates onto the swap partner. This will benefit both parties if the total amount to be paid by each is lower than before the swap. This is possible if the loan period for the swap partner ends before the LIBOR is expected to increase. In that sense, while the mentioned company might be paying a fixed rate that is higher than LIBOR for a certain amount of time during the project, that fee will become less than what will be paid if it retained the floating interest rate if LIBOR increases as speculated. For example, if the mentioned company pays a 6% fixed rate for 20 years, and the swap partner pays 5% LIBOR for 5 years, then both parties will realize benefits if the LIBOR increases to over 6% after the 5 year loan period of the swap partner ends.

7.4.2.3 Options

Options are instruments that represent contracts written between two parties, a buyer and a seller, that gives the buyer an option to buy or sell an asset, without being obliged to do so, at a fixed price. Buying an asset at a fixed price is referred to as a call option, while selling at a fixed price is referred to as a put option. The option is bought from an option seller who either owns or does not own the asset itself. Purchasing an option would shift the risk of loss on asset prices to the option seller (Finnerty, 2013; Yescombe, 2007).

Assume a company decides to purchase shares of another corporation but does not want to take the risk of fluctuating share prices. The company decides to purchase a call option instead, and pays an option seller a fee. For example, the company decides to buy call options on 30 shares, each priced at $100. It also agrees to pay the option seller $5 on each share, meaning that if the company does not exercise its option to buy the shares, the option seller would make $150. However, if the shares increase in value, and the company decides to buy the shares, then the option seller would lose an amount equal to the appreciation in asset price. As mentioned earlier, the use of options shifts the risk of loss in value of an asset to the option seller; however, purchasing an option is not free, the buyer still needs to pay the option seller a fee in order for the option seller to accept the risk.

While the use of an option hedges the buyer against the risk of loss on asset prices, it also offers the buyer an opportunity for making gains. In the discussed example, if the buyer then decides to exercise its call option and buy the shares at $100, it could then sell those shares at a price higher than $100 and make profits.

7.4.2.4 Forwards and Futures

One main difference between a forwards contract and an options contract is that the former obliges the holder to buy a specified amount of an asset at a certain point in the future. The price at which the assets are bought in the future is referred to as the exercise price; and in a forwards contract, losses or gains cannot be realized unless the exercise price differs from the actual market price at settlement date. The loss or gain cannot be realized until the exercise is paid, that is, at the contract's maturity date. In futures contracts; however, gains can be realized on a daily basis (Finnerty, 2013; Yescombe, 2007).

One example of a forwards contract is if Company X agrees to buy 300 items produced by Company Y at $10 an item, say barrels of oil, after 60 days. If, after 60 days, the price of the item rises to $12, then Company X would have realized a gain of $2 on each item. It must be noted that the gain is only realized at maturity, which increases the risk of defaulting on the contract. There are two ways a default may occur: 1) if Company X fails to pay for the product, and 2) if Company Y fails to deliver it.

Using the same example to illustrate the use of a futures contract, with the change in price of the oil per barrel being measured, the difference in price is settled at the end of every day. This reduces the risk of defaulting on the contract, since the payment period is shorter than for a forwards contract. In addition, the use of futures usually involves a clearinghouse, which is responsible for settling the payments at the end of each day. That is, if Company X fails to pay Company Y at the end of each day, the clearinghouse is responsible for paying Company Y.

The risk mitigation tools presented in this section are commonly used across a variety of projects. However, the choice of which tool to use depends on the type of risks that are inherent and on the effects of those risks. As a result, the risk mitigation step is recommended in this thesis to take place after the risk identification and risk assessment stages. In attempting to mitigate risks on a project, a risk allocation exercise must first be conducted to identify which parties are best able to handle these specific risks. Then, depending upon each risk factor, the choice of risk mitigation tool is made that will enable the decision makers to best mitigate the overall risks on a project.

The topic of risks on projects is one that has garnered much study and attention. Proper risk management is one of the most critical project success factors, and as a result, a significant portion of this thesis is dedicated to a discussion on risk management. This thesis proposes a three-stage, sequential risk management strategy that involves risk identification, assessment, and mitigation. There is no single solution that can be employed when managing risks on project, as each project has its own characteristics. However, by following a common three-stage risk management strategy, decision-makers will have a better understanding of the risks that their projects are subject to, the impact of these risks, and how to mitigate them.

8. CAPITAL BUDGETING

Capital budgeting refers to the process by which large capital projects are evaluated to assess whether an investment should be made or not. This is done through a careful analysis of the project's cash flows and examination of financial ratios. After gathering all the information necessary to construct a project's cash flows, the use of the ratios will help investors in making a decision on procuring the project. This section will explain the methods and financial ratios used to arrive at an investment decision (Boussabaine A. , 2007).

8.1 Net Present Value

The cash flow of a project will include the revenues and costs that are expected over the lifetime of the project. During the contract's lifetime, the value of money changes, and the net present value (NPV) analysis will take into account the time value of money as well as all the related revenues and costs. The formula used for NPV analysis is shown in Equation 8.1 (Ross, 1995; Yescombe, 2007).

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0 \tag{8.1}$$

Where:

$\boldsymbol{t}$ = Time periods

$\boldsymbol{r}$ = Discount rate

$\boldsymbol{C_t}$= Cash flow during period t

$\boldsymbol{C_0}$= Initial investment

The time periods depend on the contract length and on the time at which payments are made. The discount rate is used to measure the effect of time value of money, and companies typically use the weighted average cost of capital (WACC) as the discount rate in their analysis. The WACC is, as its name suggests, a measure of a company's cost of capital weighted according to the proportion of each capital component. Financial analysts will use the WACC to get an idea of what a satisfactory return on the funds should be for investors in a project. Equity and debt capital investors will require different returns on the funds they invest in the project, and the WACC weights the returns that each investor requires. The equation used to calculate the WACC is shown below to further illustrate how it is obtained (Lee & Lee, 2006).

$$WACC = \frac{E}{V_c} * R_e + \frac{D}{V_c} * R_d * (1 - T_c) \tag{8.2}$$

Where:

$E =$ Market value of equity capital

$D =$ Market value of debt capital

$V_c =$ Market value of total capital

$R_e =$ Cost of equity

$R_d =$ Cost of debt

$T_c =$ Corporate tax rate

$\frac{E}{V_c} =$ Equity proportion of total funds

$\frac{D}{V_c} =$ Debt proportion of all funds

8.2 Internal Rate of Return

The internal rate of return (IRR) is another metric used to measure the viability of investments. It helps decision makers decide whether to move forward with an investment, and helps in deciding among multiple investment options. Investors usually have a pre-specified minimum rate of return which is usually the WACC that they would like to achieve from the investment; the minimum rate of return is then compared with the project's IRR to make an investment decision. When comparing various potential projects, investors generally select the one that will achieve the highest IRR (Grayson, 2015).

The formula used to calculate IRR is the same as that for NPV. The cash flow values of the investment are inserted, as would be done for an NPV calculation, but the value of IRR is achieved by setting NPV equal to zero and calculating r in the NPV equation. The IRR is then usually compared against the WACC to decide whether an investment is profitable or not to the decision makers. If several projects are being evaluated at once, the one with the highest IRR is selected.

8.3 Return on Investment and Equity

Another metric that can be used to decide on an investment is the return on investment (ROI). ROI helps measure the efficiency of an investment, by calculating the amount of return that is made on an investment relative to the costs. The formula used to calculate ROI is shown as follows (Phillips & Phillips, 2010):

$$ROI = \frac{Gain\ from\ Investment - Cost\ of\ Investment}{Cost\ of\ Investment} \tag{8.3}$$

A positive ROI is associated with profitable investments, and is compared with other investment options to arrive at an investment decision.

In order to measure the effectiveness of an investment, the return on equity (ROE) metric is used. It also measures the profitability of an investment by calculating the profits generated from the equity invested in the project. The equation used to calculate ROE is shown in Equation 8.4:

$$ROE = \frac{Net\ Income}{Shareholders'\ Equity} \tag{8.4}$$

8.4 Payback Period

Calculating the payback period is common for PPP projects. Often, investors want to know when they are expected to recover their investments, which would also affect their decision to invest. The payback period gives an estimate of the time required to get back the cost put into the investment, and it is calculated according to the following equation:

$$Payback\ Period = \frac{Cost\ of\ Project}{Annual\ Cash\ Inflows} \tag{8.5}$$

The payback period only provides an estimate of the time needed to recover an investment, but not an accurate measure. It has two noticeable shortcomings, the first is that it does not give a description of profitability, since it does not measure benefits after the payback period. Second, it neglects the time value of money. Therefore, the payback period is not a recommended metric to guide investors in making decisions (Weingartner, 1969; Boardman, Reinhart, & Celec, 1982).

8.5 Debt-to-Equity Ratio

The debt-to-equity ratio (D/E) measures a company or project's liabilities relative to its shareholders' equity. The D/E provides a measure of how much debt is being used to finance a project relative to the amount of equity shareholders' have invested. The D/E also reflects the leverage that a company or project has, or a measure of its financial risk, which means that the greater the D/E the greater financial risk the company or project will potentially incur. However, a high D/E also indicates that potential investors will earn more. This could happen if the debt amount helps the project generate more revenues than if no debt was used, and the earnings could be distributed among the same number of shareholders. It is important to note that it would only be beneficial to the shareholders if the earnings outweigh the cost of debt or the interest rate. The formula used to calculate D/E is shown in Equation 8.6 (Yescombe, 2007).

$$^{D}/_{E} = \frac{Total\ Liablities}{Shareholders'Equity} \tag{8.6}$$

A measure similar, but less common than D/E, is the debt ratio. It measures the total company or project debts relative to the assets. It also represents leverage, and thus the financial risk. The formula used to measure the debt ratio is shown in Equation 8.7.

$$Debt\ Ratio = \frac{Total\ Debt}{Total\ Assets} \tag{8.7}$$

8.6 Cover Ratios

In addition to assessing the financial viability of projects, investors will also consider their ability to service the projects debt obligations. There are several ratios that can be used to determine if a company will be able to service its debts. In a project finance scheme, the project itself will have to be able to generate sufficient funds to cover the cost of borrowing; therefore, using these ratios with the project's information alone, without regard to the company as a whole, is done.

One commonly used ratio is the debt-service coverage ratio (DSCR), which measures the ability of a project's cash flow to service its debt. The formula used to calculate DSCR is shown in Equation 8.8 (Yescombe, 2007).

$$DSCR = \frac{Net\ Operating\ Income}{Total\ Debt\ Service} \tag{8.8}$$

Where:

Net Operating Income =	Total Revenue – Operating Expenses
Total Debt Service =	All debt obligations due in the coming year, i.e., current debt obligations

A DSCR value greater than 1 means that the company or project has enough funds to service debt obligations. A DSCR of less than 1 means that there are not enough funds to service the debt. For example, if the DSCR was calculated to be 0.9, the company or project has 90 percent of the required funds to pay off the debt obligations.

The loan life coverage ratio (LLCR) is another metric used to measure the ability to service debt payments. It is a simple ratio that is calculated by dividing the NPV of an investment by its senior debt. The use of this measure is more common among lenders who wish to know if the borrower will be able to generate enough funds to pay the required debt obligations.

8.7 Solvency Ratio

The solvency ratio also measures a company or project's cash flow to service its debt obligations. Instead of using net income; however, it incorporates depreciation to measure cash flow instead of net income, which provides a more accurate estimate if the project's assets depreciate greatly over the project's life-cycle. The lower the solvency ratio, the less likely that it would be able to fulfill its debt payments. The formula used to measure the solvency ratio is shown in Equation 8.9 (James, 1996; Holmstrom & Tirole, 1997).

$$Solvency\ Ratio = \frac{Net\ Income + Depreciation}{Total\ Liablities} \tag{8.9}$$

8.8 Value for Money

The public partner in a PPP does not generally enter into an agreement to achieve profits. Its main purpose is achieving the best outcome with the taxpayers' money. Therefore, in order to measure the viability of PPPs, the public partner conducts a value for money (VfM) analysis. The main purpose of the VfM analysis is to compare the total benefits that have been gained by procuring the project using a PPP arrangement, making it similar to a cost-benefit analysis. A project is assumed to achieve value for money if it yields a net gain to the taxpayers' money when compared to procuring the project through conventional methods, referred to as the public sector comparator (PSC). The exact definition of a PSC is a matter of debate, as there are different approaches to the matter. Quiggin, 2014, defines it as a single number which measures the cost of providing a service or facility under conventional methods. Tis benchmark is then used to measure if a PPP achieves value for money. Alternately, Grimsey & Lewis, 2007, define it as the entire process of comparing the cost of providing the service using conventional methods and using a PPP (Grimsey & Lewis, 2007). In some countries, conducting a PSC study is a legal requirement in order to proceed with a PPP project (European Investment Bank, 2015). The comparison process should take into consideration the total life-cycle cash flows, which are adjusted for risk, as mentioned earlier. The principle of risk transfer is essential to the VfM process, since one of the main differences between a conventional procurement method and a PPP is how risks are shared. Figure 8.1, adopted from Grimsey & Lewis, 2004, gives a basic idea of the comparison made using a PSC to get an estimate of the value for money.

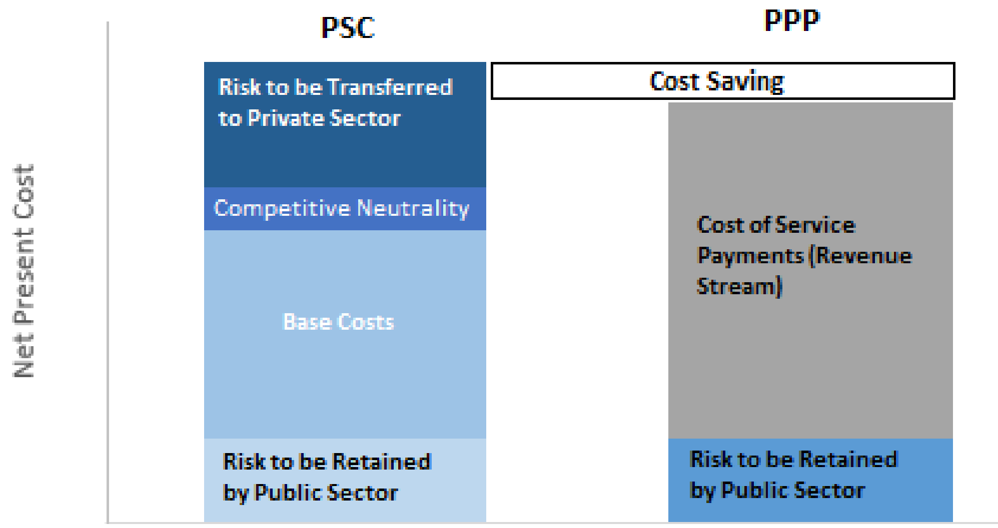

Figure 8.1 Public Sector Comparison with PPP (Grimsey & Lewis, 2004)

The PSC is calculated by taking into consideration the factors shown in the Figure 8.1 The risks that are retained by the private sector are the same for both the PPP and the PSC alternatives, since in both cases, these risks are borne by the public partner. Base costs refer to the cost of procuring the service under conventional methods, and includes the initial investment and operations and maintenance costs. Competitive neutrality is a term that refers to the costs that the private sector pays, but the public sector does not have to pay. By calculating these costs, such as taxes, it is assumed that the public sector does not gain an advantage over the private sector by not paying these costs. The risk to be transferred to the private sector are also calculated as part of the PSC, since they will be borne by the public sector if the project is procured by conventional methods, but they are not calculated as part of the PPPs total costs (Grimsey & Lewis, 2004).

The PSC is estimated by assuming a procurement method that will be funded entirely by the government, but will bear the least cost to the government, which could be a design-bid-build or a design-build, for example, whichever has a lower cost. The calculation of the PSC should also incorporate any efficiencies that the public sector may contribute to, such as tax cuts. For this reason, different scenarios of the PSC are modeled in order to make sure the PPP achieves a value for money. Moreover, the net present value (NPV) of the costs is calculated in order to compare with the PPP alternative. Therefore, the PPP is considered to achieve VfM if the NPV of its costs are lower than those of the PSC (Yescombe, 2007; European Investment Bank, 2015; Grimsey & Lewis, 2004) .

In calculating the life-cycle costs of a project under both the PPP and the conventional procurement scenarios, a discount rate must be selected. The discount rate varies depending on the requirements of each country in which the project is being procured. For example, in Australia, the capital asset pricing method is used to come up with the discount rate, while in Canada the weighted average cost of capital (WACC) is used. The United Kingdom uses a fixed rate, and in the United States, the Office of Management and Budget (OMB) issue an annual rate for use in the PSC analysis.

There are several limitations to the use of the PSC as a measurement of value for money of PPP projects. One such limitation is that the decision is often narrowed down to a single number that involves forecasting and uncertainty. This simple comparison between two numbers makes the decision rather simplistic, and is one of the negatives of using the PSC. Also, Heald (2003) claims that the PSC lacks robustness, because it narrows the decision down to a single value. Bain (2010) also claims that a PSC is often a tool that lacks transparency, and as such, it raises suspicion concerning its suitability to provide a decision on large, capital intensive projects.

The capital budgeting metrics presented in this chapter provide a complete overview of metrics that investors and decision-makers use when making an investment decision. Not all of the presented metrics can provide definitive values that will lead the decision-makers to invest in a project, but they can be used as a preliminary evaluation.

One example is the payback period, which neglects the time value of money, making it only viable as a preliminary indication of when the investor could expect to have a return on investment. However, it should not be used as the only metric that would guide an investment decision. It is recommended that investors and decision-makers should conduct a thorough capital budgeting exercise, and examine all the ratios presented in this chapter before making an investment decision. The analysis should be led by the NPV and IRR analyses, and followed by computing return on investment and equity, cover ratios, and solvency ratio. In addition, a value for money analysis using a public sector comparator can be used to give preliminary guidance on the expected benefits of a PPP investment; however, it should not guide the investment decision.

9. CONCLUSION

The use of PPPs in urban projects has proliferated in the past few years. This is due, mainly, to the financial investment that private investors can provide for large-scale urban public projects. Also, the private sector has realized the opportunity for profits from investing in such projects. The results of PPP ventures have varied from one project to another, but they have generally been viewed as an overall success. The main reasons that have been attributed to the failures of certain PPP projects have been the inability of the private partner to repay its debts, resulting in bankruptcy filings. This is a result of less than expected revenues being gained, in which several factors can be attributed to this; these factors are mainly related to uncertainties involved with a PPP project and inaccuracies in forecasting key parameters such revenue streams, as well as inadequacy in assessing the effects of risk on the financial viability of the project.

This thesis proposes a framework for assessing an urban public-private partnership project's financial viability, which would provide investors and public officials alike with an overview of the complexities involved in assessing a project's financial viability. The proposed framework takes into consideration the effects of several factors on the decision, such as the project's length, the type of PPP arrangement, the financial structure, the project's cash flow, and the effects of risk. These factors, when combined, have a significant impact on the profitability of a project. This thesis provides an overview of each component and shows how they all interact with each other in terms of making a financial viability decision.

First, before entering into a PPP arrangement, its use should be justified. Experience has shown that a PPP can offer great benefits to governments that face budgetary limits. Despite the complex nature involved in setting up a PPP contract, from deciding on the financing aspect, to the revenue structure, and to the risk allocation, a PPP can be a successful alternative to traditional procurement. This is particularly highlighted in situations when an urban project needs to be procured and the government does not have the resources, whether financial or technical, to do it alone. While the need for the project governs the public entity's decision in developing countries, this decision is based on a Value for Money (VfM) analysis in developed countries.

After agreeing on a PPP approach to project delivery, an in-depth financial viability study must be made in order to decide on whether to move forward with the investment. The framework proposed in this thesis suggests starting with listing out the main inputs to the financial viability study, which include the type of PPP arrangement, the contract duration, and the financial structure. The PPP arrangements that are presented vary significantly from one another, they range from only offering services to designing, building, financing, operating, and maintaining an entire project. It has been found that there is not one contract arrangement that suits all PPP projects, but the capabilities of each party, along with their intended goals for the project, need to be considered before making a decision which PPP arrangements to select It was also found that the choice of contract duration should be made to ensure that each party achieves their expected goals from the project. Moreover, the choice of financial structure was found to vary depending on the project participants and on their expected goals.

The financing of the PPP agreement is one of the most important factors that could determine the success or failure of a project. PPP projects are associated with large capital investments and long contract durations, meaning that, in most cases, a mixture of both debt and equity is needed to be able to finance a project. One of the first decisions that the private entity should make is whether to create a Special Purpose Vehicle (SPV) to procure the project, and finance it based on project financing. The use of project finance is recommended when the project is able to independently generate the necessary cash flows to fund the project over its life cycle. Then, a decision should be made regarding the amount of funding that need to be raised, and specifically what mixture of debt and equity should be used, taking into consideration the risks associated with each. It is found that there is no single mixture of debt and equity that should be employed for every project; rather the mixture varies across projects. However, it is generally common for debt to make up the majority of the funding.

After establishing the type of PPP arrangement, the contract duration, and the financing structure of the project, its cash flows must be studied to address whether the project should be procured. Costs and revenues for PPP projects vary mainly depending on the type of PPP arrangement and the financial structure. Each project has its own costs and revenues; however, there are common cost and revenue categories that exist across projects. Costs are generally studied based on which stage of the life cycle they occur in, while revenues are classified as either user-based or government-based. The process of detailing the costs and benefits of a project requires careful analysis and continuous follow-up throughout the project's life cycle.

After describing the costs and benefits that are associated with a project, it was found that an essential step in the financial viability study must then be followed, which is risk management. This thesis recommends a three-stage sequential process for risk management, which includes risk identification, assessment, and mitigation. The risk identification stage involves an in-depth study of all the risks that could affect the project, which is essential in order to be able to analyze the possible impacts of the risk on the project. It is recommended to follow a risk checklist when identifying the risks, in which the different risk factors are grouped into one of the many possible categories. Risk identification is a process that should take place at the very early stages of the project, and will continue throughout the project's life cycle. Afterwards, the risk assessment stage must be completed in order to be able to identify the potential impacts of risks on a project. It was found that the risk assessment should start with a sensitivity analysis of the risk variables identified earlier. Afterwards, risk assessment methods should be used to study the impact of these sensitive risks. Several methods are presented in this thesis that can be used to assess risk. Each method has its own benefits and limitations, and each should be carefully studied in order to decide on which to use. In cases in which there is an established and known sequence of risks and decisions, which yield outcomes that can be discretized, it was found that decision trees based on Bayesian Analysis is recommended. However, if there is no established sequence, and the risk outcomes cannot be discretized, then it was found that Monte Carlo Simulation, the Method of Moments, and Artificial Neural Networks were able to provide an accurate assessment of the risk variables. It was found that whenever the distribution of possible values that risk variables might take is known, and the correlation among the variables is identified, Monte Carlo Simulation can be employed. Otherwise, it was found that the use of the Method of Moments or Artificial Neural Networks is preferred. As a result, a mixture of more than one risk method among Monte Carlo Simulation, Method of Moments and Artificial Neural Networks is recommended; since they can combine to assess the various types of risk variables that were identified. Finally, the risk mitigation step takes place, which is aimed at reducing the impact of risk on the project. Risk mitigation was found to involve risk allocation and the use of risk mitigation tools. In allocating risks to either the public or the private entity, a three-step analysis of the entities must be considered, and it includes: the ability of the entity to influence the specific risk, the ability of the entity to influence the effect of the risk on the project value, and the ability of the entity to absorb the risk at the lowest cost. This will ensure that risk is allocated to the party best able to handle it.

Afterwards, a risk-adjusted cash flow is constructed, which contains the range of revenue and cost variables identified from the risk management stage, along with their probabilities and expected values. Then, the thesis moves to describe the different capital budgeting equations and ratios that are used to provide the decision maker with an estimate of the projects financial viability. Several tools were presented for capital budgeting, but it was found that the NPV is the most commonly used method; and it is the one that should guide the decision. However, the decision maker should also study the cover ratios, solvency ratio, internal rate of return, and conduct a value for money analysis to obtain a more complete view on the financial implications of undertaking the project.

BIBLIOGRAPHY

Akintoye, A., & Beck, M. (2009). *Policy, Finance & Management for Public-Private Partnerships.* Oxford: Blackwell Publishing Ltd.

Akintoye, A., Hardcastle, C., & Beck, M. (2003). *Public-Private Partnerships: Managing Risks and Opportunities.* Blackwell Publishing Ltd.

Arndt, R. H. (1998). Risk Allocation in the Melbourne City Link Project. *The Journal of Structured Finance, 4*(3), 11-24.

ASCE. (2013). *2013 Report Card for America's Infrastructure*. Retrieved March 10, 2015, from American Society for Civil Engineers: http://www.infrastructurereportcard.org/

Asian Development Bank. (2008). *PPP Handbook.* Manila: Asian Development Bank.

Asian Development Bank. (2010). *Tool Kit for Public-Private Partnerships in Urban Bus Transport for the State of Maharashtra, India.* Mandaluyong City: Asian Development Bank.

Bedford, T., & Cooke, R. (2001). *Probabilistic Risk Analysis: Foundations and Methods.* Cambridge University Press.

Best, P. (2000). *Implementing Value at Risk.* Wiley.

Boardman, C. M., Reinhart, W. J., & Celec, S. E. (1982). THE ROLE OF THE PAYBACK PERIOD IN THE THEORY AND APPLICATION OF DURATION TO CAPITAL BUDGETING. *Journal of Business Finance & Accounting*, 511-522.

Bouejla, A., Chaze, X., Guarnieri, F., & Napoli, A. (2014). A Bayesian Network to Manage Risks of Maritime Piracy against Offshore Oil Fields. *Safety Science*, 222-230.

Boussabaine, A. (2007). *Cost Planning of PFI and PPP Building Projects.* Routledge.

Boussabaine, A. (2014). *Risk Pricing Strategies for Public-Private Partnership Projects.* Liverpool: Wiley-Blackwell.

Boussabaine, A., & Kaka, A. (1998). A neural networks approach for cost flow forecasting. *Construction Management and Economics* , 471-479.

Bult-Spiering, M., & Dewulf, G. (2008). *Strategic Issues in Public-Private Partnerships: An International Perspective.* Wiley-Blackwell.

Burger, P., & Hawkesworth, I. (2011). How To Attain Value for Money: Comparing PPP and Traditional Infrastructure Public Procurement. *OECD Journal on Budgeting*.

Cangiano, M., Hemming, R., & Ter-Minassian, T. (2004). *Public-Private Partnerships: Implications for Public Finances.* International Monetary Fund.

Carbonara, N., Costantino, N., & Pellegrino, R. (2014). Concession Period for PPPs: A win-win model for a fair risk sharing. *International Journal of Public Management*, 1223-1232.

Carmichael, D. G. (2015). *Infrastructure Investment: An Engineering Perspective.* Boca Raton: CRC Press.

Chang, M. (2011). *Monte Carlo Simulation for the Pharmaceutical Industry: Concepts, Algorithms, and Case Studies.* CRC Press.

Chang, T. (2011). Article Chang, T. S.: A Comparative Study of Artificial Neural Networks, and Decision Trees for Digital Game Content Stocks Price Prediction. *Expert Systems with Applications, 38*(12), 14846-14851.

Chau, K. (1995). The validity of the triangular distribution assumption in Monte Carlo simulation of construction costs: empirical evidence from Hong Kong. *Construction Management and Economics, 13*, 15-21.

Chua, D., Kog, Y., Loh, P., & Jaselskis, E. (1997). Model for construction budget performance-neutral network approach. *Journal of Construction Engineering Management*, 214-222.

CMAA. (2012). *An Owner's Guide To Project Delivery Methods.* The Construction Management Association of America.

Crouhy, M., Galai, D., & Mark, R. (2000). A comparative analysis of current credit risk models. *Journal of Banking and Finance, 24*, 59-117.

Cruz, C. O., & Marquez, R. C. (2013). *Infrastructure Public-Private Partnerships: Decision, Management and Development.* Lisbon: Springer.

Damnjanovic, I. (2006). *A Risk Based Approach to Modeling Life Cycle Costs Associated With Warranty Specifications for Transportation Infrastructure.* University of Texas at Austin.

Damodaran, A. (2003). *Value at Risk.* Retrieved June 20, 2015, from NYU Stern : http://people.stern.nyu.edu/adamodar/pdfiles/papers/VAR.pdf

Damodaran, A. (2008). *Probabilistic Approaches: Scenario Analysis, Decision Trees and Simulations.* Retrieved August 20, 2015, from NYU Stern: Damodaran Online: http://people.stern.nyu.edu/adamodar/pdfiles/papers/probabilistic.pdf

Delmon, J. (2010). *Understanding Options for Public-Private Partnerships in Infrastructure.* Washington DC: The World Bank.

Dey, P., & Ogunlana, S. (2001). Project time risk analysis through simulation. *Cost Engineering, 43*(7), 24-32.

Ehrhardt, D., & Irwin, T. (2004). *Avoiding Customer and Taxpayer Bailouts in Private Infrastructure Projects .* Washington, DC: The World Bank.

Engel, E., Fischer, R., & Galetovic, A. (2014). *The Economics of Public-Private Partnerships: A Basic Guide.* Cambridge University Press.

European Commission. (2003). *GUIDELINES FOR SUCCESSFUL PUBLIC - PRIVATE PARTNERSHIPS.* Brussels: European Commission.

European Investment Bank. (2015). *How to Prepare, Procure and Deliver PPP Projects.* Retrieved from European Investmetnt Bank: http://www.eib.org/epec/g2g/i-project-identification/12/124/index.htm

European Investment Bank. (2015). *The EPEC PPP Guide*. Retrieved August 20, 2015, from European Investment Bank: http://www.eib.org/epec/g2g/i-project-identification/12/122/index.htm

Farquharson, E., Mastle, C. T., Yescombe, E., & Encinas, J. (2011). *How to Engage with the Private Sector in Public-Private Partnerships in Emerging Markets.* Washington, DC: The World Bank.

FHWA. (2010). *P3 Concessions for Highway Projects: A Primer.* Washington, DC: FHWA.
FHWA. (2013). *Financial Structuring of Public-Private Partnerships.* Washington, DC: FHWA.
FHWA. (2013). *Financial Structuring of Public-Private Partnerships.* Retrieved September 10, 2015, from Federal Highway Administration: http://www.fhwa.dot.gov/ipd/pdfs/p3/factsheet_04_financialstructuring.pdf
FHWA. (2014). *Innovative Program Delivery*. Retrieved April 20, 2015, from Federal Highway Administration: http://www.fhwa.dot.gov/ipd/p3/defined/long_term_lease.aspx
FHWA. (2015). *Federal Debt Financing Tools*. Retrieved from US Federal Highway Administration: https://www.fhwa.dot.gov/ipd/finance/tools_programs/federal_debt_financing/private_activity_bonds/
Fight, A. (2006). *Introduction to Project Finance.* Oxford: Butterworth-Heinemann.
Finnerty, J. D. (2013). *Project Financing: Asset-Based Financial Engineering.* John Wiley & Sons, Ltd.
GAO. (1999). *Public-Private Partnerships: Terms Related to Building and Facility Partnerships.* Washington, DC: Government Accounting Office.
Grayson, L. (2015). *Internal Rate Of Return: An Inside Look* . Retrieved from Investopedia: http://www.investopedia.com/articles/07/internal_rate_return.asp
Grimsey, D., & Lewis, M. (2002). Evaluating the risks of public-private partnerships for infrastructure projects. *International Journal of Project Management*, 107-118.
Grimsey, D., & Lewis, M. (2004). *Public Private Partnerships: The Worldwide Revolution in Infrastructure Provision and Project Finance.* Edward Elgar.
Grimsey, D., & Lewis, M. (2007). Public Private Partnerships and Public Procurement . *A Journal of Policy Analysis and Reform*, 171-188.
Haimes, Y. (1998). *Risk Modeling, Assessment, and Management.*
Haimes, Y., Li, D., & Tulsiani, V. (1990). Multiobjective Decision-Tree Analysis. *Risk Analysis*, 111-127.
Hall, J. (1998). Private Opportunity, Public Benefit? *Fiscal Studies*, 121-140.
Han, Z. (2013). *Procedures and Resources for Analyses Related to Public-Private Partnerships.* Austin: The University of Texas at Austin.
Han, Z., Stone, C., & Zhang, Z. (2014). Reliability-based Approach to Optimizing Pavement Preventive Maintenance Cycles Using the Method of Moments. *Transportation Research Board 93rd Annual Meeting* (p. 19). Washington, DC: Transportation Research Board.
Hardcastle, C., & Boothroyd, K. (2003). *Public Private Partnerships: Managing Risks and Opportunities.* Blackwell Science.
Heinze, K. (1996). *Cost Management of Capital Projects.* New York: M. Dekker.
Holmstrom, B., & Tirole, J. (1997). Financial Intermediation, Loanable Funds, and the Real Sector. *The Quarterly Journal of Economics* , 663-691.

Infrastructure Australia. (2008). *National Public Private Partnership Guidelines.* The Australian Government.

Infrastructure Australia. (2008). *National Public Private Partnership Guidelines.* Australian Government.

Irwin, T. (2007). *Government Guarantees Allocating and Valuing Risk in Privately Financed Infrastructure Projects.* Washington, DC: The World Bank.

James, C. (1996). Bank Debt Restructurings and the Composition of Exchange Offers in Financial Distress. *The Journal of Finance*, 711-727.

Jin, X., & Doloi, H. (2008). Interpreting risk allocation mechanism in public–private partnership projects: an empirical study in a transaction cost economics perspective. *Construction Management and Economics*, 591-603.

Jin, X.-H., & Zhang, G. (2011). Modelling optimal risk allocation in PPP projects using artificial neural networks. *International Journal of Project Management*, 591-603.

Jorion, P. (2000). Risk Management Lessons from Long-Term Capital Management. *European Financial Management*, 277-300.

Ke, Y., Wang, S., & Chan, A. P. (2010). Risk Allocation in Public-Private Partnership Infrastructure Projects: Comparative Study. *Journal of Infrastructure Systems*, 343-351.

Khan, A. (2013). Risk factors in toll road life cycle analysis. *Transportmetrica A: Transport Science*, 408-428.

Kliem, R., & Ludin, I. (1997). *Reducing Project Risk.* Gower Publishing, Ltd.

Koller, G. (1999). *Risk Assessment and Decision Making in Business and Industry.* CRC Press.

Kwak, Y. H., Chih, Y., & Ibbs, C. W. (2009). Towards a Comprehensive Understanding of Public Private Partnerships for Infrastructure Development. *California Management Review, 51*(2), 51-78.

Lam, K., Wang, D., Lee, P., & Tsang, Y. (2007). Modeling risk allocation decision in construction contracts. *International Journal of Project Management*, 485-493.

Lee, A. C., & Lee, C.-F. (2006). *Encyclopedia of Finance.* New York : Springer.

Li, B., Akintoye, A., Edwards, P., & Hardcastle, C. (2005). Critical success factors for PPP/PFI projects in the UK Construction Industry. *Construction Management and Economics*, 459-471.

Li, B., Akintoye, A., Edwards, P., & Hardcastle, C. (2005). The Allocation of Risk in PPP/PFI Construction Projects in the UK. *International Journal of Project Management*, 25-35.

Ma, B., Si, W., Zhu, D.-p., & Wang, H.-n. (2014). Applying Method of Moments to Model the Reliability of Deteriorating Performance to Asphalt Pavement under Freeze-Thaw Cycles in Cold Regions. *Journal of Materials in Civil Engineering*.

McKinsey. (2013). *McKinsey Working Papers on Risk, Number 52 Frank Beckers Nicola Chiara Adam Flesch Jiri Maly Eber Silva Uwe Stegemann November 2013 © Copyright 2013 McKinsey & Company A risk-management approach to a successful infrastructure project: Initiation, financing, and execution.* McKinsey & Company.

Menheere, S., & Pollalis, S. (1996). *Case Studies on Build Operate Transfer.* Delft: Delft University of Technology.

Mishra, S., Khasnabis, S., & Swain, S. (2015). Incorporating uncertainty and risk in transportation investment decision-making. *Transportation Planning and Technology, 38*(7), 738-760.

Mukta Paliwal, U. A. (2009). Neural networks and statistical techniques: A review of applications. *Expert Systems with Application*, 2-17.

Munn, J. (2006). *Modeling Risk : Applying Monte Carlo Simulation, Real Options Analysis, Forecasting, and Optimization Techniques.* Wiley.

NCPP. (2015). *Types of Public Private Partnerships*. Retrieved 2015, from The National Council for Public Private Partnerships: http://www.ncppp.org/ppp-basics/types-of-partnerships/

Ng, A., & Loosemore, M. (2007). Risk allocation in the private provision of public infrastructure. *International Journal of Project Management, 25*(1), 66-76.

Ng, S. T., Xie, J., Cheung, Y. K., & Jefferies, M. (2007). A Simulation Model for Optimizing the Concession Period of Public-Private Partnerships Schemes. *International Journal of Project Management, 25*(8), 791-798.

NTSA. (2004). *Public-Private Partnership Manual - Module 4: PPP Feasibility Study.* South Africa: National Treasury of South Africa.

Pantelias, A. (2009). *A Methodological Framework for Probabilistic Evaluation of Financial Viability of Transportation Infrastructure under Public-Private Partnerships.* Austin: The University of Texas at Austin.

Pantelias, A., & Zhang, Z. (2010). Methodological Framework for Evaluation of Financial Viability of Public-Private Partnerships: Investment Risk Approach. *Journal of Infrastructure Systems*.

Peng, W., Cui, Q., & Chen, J. (2014). Option Game Model for Optimizing Concession Length and Public Subsidies of Public–Private Partnerships. *Journal of the Transportation Research Board*, 109-117.

Phillips, P. P., & Phillips, J. J. (2010). Return on Investment. In K. H. Silber, & W. R. Foshay, *Handbook of Improving Performance in the Workplace: Volumes 1-3* (pp. 823-847). Pfeiffer.

PPP Council. (2015). *Models of Public Private Partnerships*. Retrieved June 14, 2015, from The Canadian Counsel for Public Private Partnerships: http://www.pppcouncil.ca/resources/about-ppp/models.html

PwC. (2010). *Public-Private Partnerships: The US Perspective.* PriceWaterhouseCoopers.

Quiggin, J. (2004). Risks, PPPs and the Public Sector Comparator. *Australian Accounting Review*, 51-61.

Reuters. (2015). *SPV*. Retrieved September 11, 2015, from Financial Glossary: http://glossary.reuters.com/index.php?title=SPV

Rezaiea, K., Amalnika, M., Gereiea, A., Ostadib, B., & Shakhseniaeea, M. (2007). Using extended Monte Carlo simulation method for the improvement of risk

management: Consideration of relationships between uncertainties. *Applied Mathematics and Computation*, 1492–1501.
Ross, S. A. (1995). Uses, Abuses, and Alternatives to the Net-Present-Value Rule. *Financial Management* , 96-102.
Royal Society. (1983). *Risk Assessment: A Study Group Report.* London: Royal Society.
Rubinstein, R. Y., & Kroese, D. P. (2008). *Simulation and the Monte Carlo Method.* Wiley.
Sabol, P., & Puentes, R. (2014). *Private Capital, Public Good: Drivers of Successful Infrastructure Public-Private Partnerships.* Brookings.
Sagalyn, L. (2011). Public-Private Partnerships and Urban Governance: Coordinates and Policy Issues. In E. L. Birch, & S. M. Wachter, *Global Urbanization* (pp. 191-211). Philadelphia: University of Pennsylvania Press.
Savas, E. (2000). *Privatization and Public-Private Partnerships.* New York: Chatham House.
Savas, E. (2005). *Privatization in the City: Successes, Failures, Lessons.* Washington D.C.: CQ Press.
Songer, A., Dickermann, J., & Pescsok, R. (1997). Risk analysis for revenue dependent infrastructure projec. *Construction Management and Economics, 31*, 377-382.
Stone, J. (2013). *Bayes' Rule: A Tutorial Introduction to Bayesian Analysis.* Sebtel Press.
TCRP. (2009). *A Guidebook for the Evaluation of Project Delivery Methods.* Washington, D.C.: Transportation Research Board.
TxDOT. (2015). *2015 Educational Series: Comprehensive Development Agreements* . Retrieved September 09, 2015, from Texas Department of Transportation : http://ftp.dot.state.tx.us/pub/txdot-info/sla/education_series/cda.pdf
Vassallo, J. M. (2006). Traffic Risk Mitigation in Highway Concession Projects: The Experience of Chile . *Journal of Transport Economics and Policy, 40*(2), 359-381.
VDTF. (2001). *Partnerships Victoria: Risk Allocation and Contractual Issues.* Australia: Victorian Department of Treasury and Finance.
Vinter, G. (2006). *Project Finance: A Legal Guide.* London: Sweet & Maxwell.
Wang, S. Q., Tiong, R. L., Ting, S. K., & Ashley, D. (2000). Evaluation and Management of Political Risks in China's BOT Projects. *Journal of Construction Engineering and Management*, 242-250.
Weingartner, H. M. (1969). Some New Views on the Payback Period and Capital Budgeting Decisions. *Management Science*, 594-607.
World Bank. (2014). *Main Financing Mechanisms for Infrastructure Projects* . Retrieved March 10, 2015, from PPPIRC: http://ppp.worldbank.org/public-private-partnership/financing/mechanisms
World Bank. (2014). *PPP Arrangements*. Retrieved April 10, 2015, from PPPIRC: http://ppp.worldbank.org/public-private-partnership/agreements
World Bank. (2014). *PPP Arrangements / Types of Public-Private Partnership Agreements*. Retrieved February 14, 2015, from World Bank: http://ppp.worldbank.org/public-private-partnership/agreements

World Bank. (2014). *Risk Allocation, Bankability and Mitigation in Project Financed Transactions* . Retrieved August 15, 2015, from PPPIRC: http://ppp.worldbank.org/public-private-partnership/financing/risk-allocation-mitigation

World Bank. (2014). *Sources of Financing* . Retrieved February 12, 2015, from World Bank PPP IRC: http://ppp.worldbank.org/public-private-partnership/financing/sources

World Bank. (2015, March 05). *Government Objectives: Benefits and Risks of PPPs*. Retrieved from The World Bank Public Private Partnership in Infrastructure Resource Center: http://ppp.worldbank.org/public-private-partnership/overview/ppp-objectives

World Bank. (2015, May 03). *Main Financing Mechanisms for Infrastructure Projects*. Retrieved September 20, 2015, from The World Bank Public-Private Partnership in Infrastructure Resource Center: http://ppp.worldbank.org/public-private-partnership/financing/mechanisms

World Bank. (2015, April 24). *Project Finance – Key Concepts*. Retrieved August 20, 2015, from The World Bank Public-Private Partnership in Infrastructure Resource Center: http://ppp.worldbank.org/public-private-partnership/financing/project-finance-concepts

World Bank; ADB; IDB. (2014). *Public-Private Partnerships Reference Guide.* Washington, DC: The World Bank.

Xie, J., & Ng, S. T. (2013). Multiobjective Bayesian Network Model for Public-Private Partnership Decision Support. *Journal of Construction Engineering and Management, 139*(9), 1069-1081.

Yescombe, E. (2007). *Public-Private Partnerships: Principles of Policy and Finance.* Oxford: Elsevier Ltd.

Yuwen, W., & Zhang, Z. (2013). *Simulation of Investment Returns of Toll Projects.* Washington, DC: Transportation Research Board.

Zhang, X. (2005). Critical Success Factors for Public–Private Partnerships in Infrastructure Development. *Journal of Construction Engineering and Management*, 3-14.

Zhang, Z., & Damnjanovic, I. (2006). Applying Method of Moments to Model Reliability of Pavements Infrastructure. *Journal of Transportation Engineering*, 416-424.

Zhang, Z., & Damnjanovic, I. (2006). Quantification of Risk Cost Associated with Short-Term Warranty-Based Specifications for Pavements. *Journal of the Transportation Research Board*, 3-11.

Zhao, Y.-G., & Ono, T. (2001). Moment methods for structural reliability. *Structural Safety, 23*(1), 47-75.